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**Summary of Section 13, Risk Analysis 2005 Base Year Results**

**Purpose:**

This section summarizes the results of the risk analysis for levee failures in the Delta and Suisun Marsh for the 2005 base year.

**Methods of Analysis:**

In this section, the probability of Delta island flooding as a result of levee failures is assessed under sunny-day risks, seismic risks, flood risks, and combined risks for the 2005 base year. This section also assesses the consequences of levee failures under seismic, flood, and sunny-day events. Specifically, the discussion of consequences summarizes the cost and timing of emergency response and repair actions (i.e., levee repairs), water export disruptions because of water quality issues (seismic event only), economic consequences (i.e., economic costs and economic impacts [see Section 12 for definition of these terms]), ecological consequences (i.e., effects on aquatic species, vegetation, and terrestrial wildlife), and public health and safety (i.e., potential loss of life). The results presented in this section do not include the changing risks in future years. The increase in risks for future years is presented in Section 14.

**Main Findings:**

The 2005 base case shows considerable potential for the Delta and Suisun Marsh areas to face a high risk of multiple-island failures from both seismic and flood events. The population at risk and the economic and ecological consequences of a major event can be severe in some cases. Aside from the number of islands that flood in a sequence, the economic consequences of a sequence will depend on three primary factors: which islands have flooded, the month in which the initiating event occurs, and the type of water year (wet or dry).

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## 13.1 INTRODUCTION

This section presents the results of the risk analysis associated with levee failures in the Sacramento–San Joaquin River Delta (Delta) and Suisun Marsh study area. The analyses are based on failures caused by various hazards identified by the Delta Risk Management Strategy (DRMS) under two conditions. The first condition addresses the present-day risk for the 2005 base year assuming business as usual (BAU), and the second condition addresses the future risks for 2050, 2100, and 2200. BAU is defined in the preamble to this report. The probabilities of the initiating events are combined with the probabilities of system failures (levee failures and island flooding), which in turn are combined with the simulated outcomes of hydrodynamics and salt intrusion, the economic costs and impacts, the ecological impacts, and the probability of loss of life to estimate the probable consequences. The detailed methodology used to assess the risks is described in Section 4. The development of the conditional probabilities of outcome for the topics described below is discussed in each topic's respective section in this report and in more detail in the supporting technical memoranda referenced herein.

This section also provides a brief discussion of where the uncertainties associated with these topics are represented probabilistically and where they are represented by a range of outcomes when a formal uncertainty model was not available. The representation of the topics is summarized below.

- Seismic hazard characterization uses a probabilistic model for the present and future risks.
- Flood hazard characterization uses a probabilistic model for the present and future risks.
- Climate change characterization uses a range of values for the future risks.
- Subsidence uses a range of values for the future risks.
- Wind/wave hazard characterization uses a probabilistic model for the present risks.
- Levee response to seismic hazard uses a probabilistic model for the present and future risks.
- Levee response to flood hazard uses a probabilistic model for the present and future risks.
- Emergency response and repair uses simulation of all probable hazards and levee responses and estimates the cost of repair and repair duration for each sequence.
- The hydrodynamic/salinity intrusion/water management/export impacts use simulation of all probable hazards, levee failures, and emergency responses and estimate for each sequence of levee failures the loss of freshwater that otherwise would have been exported for the State Water Project and the Central Valley Project.
- Loss of life uses full probabilistic models for hazards, levee failures, island inundation, and loss of life for the seismic and flood hazards and daytime and nighttime events.
- Economic costs and impacts use simulation of all hazards, levee failures, emergency responses, and loss of freshwater for export and estimate for each sequence of levee failures the economic costs (direct) and economic impacts (indirect).
- Ecological impacts use simulation of all hazards, selected levee failures, emergency responses, and saltwater intrusion and estimate for each sequence of levee failures the

ecological impacts. The aquatic model was developed probabilistically but was not run at this time for the reasons discussed in Section 12.

In this section we occasionally report the probability of various outcomes for selected exposure periods (e.g., 25 years or 50 years) in addition to annual probabilities. It should be noted that those probabilities reported for the various exposure periods represent today's risk and assume that no changes in the hazards, the state of the Delta, or the consequences are taking place during those exposure periods. This way of reporting is an alternate way to present the results for those more familiar with probability of failure and consequences in terms of exposure period. However, the exposure period results should not be interpreted as the projected future risks during those exposure periods. The time-dependent results are presented in Section 14. The risk results presented in this section are factored by the percent increases presented in Section 14 to assess the future risks.

Previous sections of this report describe the various modules supporting the risk assessment, the characterization of their physical processes, the approach used to develop conditional probability models, and their typical output that becomes input into the risk model. Section 4 describes the risk analysis approach used to integrate the various module outputs in the risk model. This section presents the results of the system response (levee failures) to the various hazards and the consequences of such failures as summarized below. The future risks (e.g., effects of climate change or subsidence and their consequences) are presented in Section 14.

- Hazards: seismic, flood, wind-wave, and high-tide sunny-day occurrences
- System responses:
  - Levee vulnerability and probable failure modes under the above hazards
  - Emergency response and repair: particularly the order and rate of progress for repairs, including rate of erosion of flooded islands, and costs of repair
  - Salinity impacts: the intrusion of Bay salty water in response to the levee breaches and progress in returning to normal conditions over the repair period
- Consequences: public safety, environmental, and economic impacts

This section presents the results of the analyses of risks associated with the various hazards: (1) the potential for island flooding, both combined and individually, and (2) the consequences of that flooding. In so doing, the section begins with flooding potential tied to risks from:

- Sunny-day failures
- Seismic events
- Floods
- The combined risk of inundation from all hazards

After the likelihood of flooding is presented, the results of analyses of consequences of island flooding from various hazards are discussed, for each type of hazard event (sunny-day, seismic, and flood events) and for all hazards combined, as shown below.

- Economic consequences
- Ecosystem consequences

- Public health and safety consequences

It should be noted again that in this section the results are presented as annual frequencies and probabilities for the base year or, alternatively, for various exposure periods. The results presented in this section do not include the changing risks in future years. The increases to the risks for future years are presented in Section 14.

## 13.2 PROBABILITY OF ISLAND FLOODING

The probability of island inundation (resulting from levee breach) is presented individually for each causative event: sunny-day event, seismic event, and hydrologic (flood) event. Within each, two perspectives are adopted. The first considers possible outcomes from single events, including the prospect of multiple failures from the event, and the second considers potential flooding on an island-by-island basis, not considering what may be occurring on other islands.

### 13.2.1 Sunny-Day Risk

As described in Section 9, the risk of sunny-day failures, usually associated with high tides, is developed principally from historical observations. By definition, sunny-day failures occur only in the late spring, summer, and early fall (i.e., during the low-flow season) and are likely to occur during higher tides. The expected frequencies of island failures during sunny-day conditions are summarized in Table 13-1. The results were compiled for the islands and tracts within the mean higher high water (MHHW) boundary shown in Figure 13-1. About 911 miles of Delta levees and about 75 miles of exterior levees in Suisun Marsh lie within the MHHW boundary. The expected annual frequencies of historical breaches are about $1.06 \times 10^{-4}$ /year/levee mile or 0.0969 failures/year for the Delta and $4.76 \times 10^{-4}$ /year/levee mile or 0.036 failures/year for Suisun Marsh. These rates are applied uniformly to all levees within the MHHW boundary in the respective areas.

The historical record for Suisun Marsh is limited and incomplete. The only available information on sunny-day failures for Suisun Marsh consists of two data points that only go back to 1999. Prior information is not available.

Assuming no changes to the Delta and its drivers of change, it is expected that about 4.8 sunny-day breaches will occur on average in the Delta during a 50-year exposure period or 9.7 breaches during a 100-year exposure period. It is estimated that about 1.8 sunny-day breaches will occur on average in Suisun Marsh during a 50-year exposure period or 3.6 breaches during a 100-year exposure period. These estimates will change with the future years' risk, as discussed in Section 14.

Sunny-day failures are assumed to occur one island at a time. Historically, no simultaneous sunny-day failures have been observed. Consequently, for the 2005 base case conditions, the frequency of two or more sunny-day failures occurring during the same sunny-day, high-tide event is assumed to be insignificant. Further, it is assumed that the likelihood of increased seepage on adjacent islands that leads to a levee breach that results in additional island flooding is small (based on the occurrence of such events in the historical records). This assessment is consistent with the 2004 Jones Tract sunny-day failure that showed no adverse conditions that could have led to the failure of another island. However, increased seepage flows were observed on adjacent islands after the Jones Tract failure (i.e., Woodward Tract [DWR 2004]).

### 13.2.2 Seismic Risk

When an earthquake occurs, all Delta and Suisun levees may be subject to dynamic loading and potential failure within several minutes—essentially simultaneously. If an earthquake is strong enough to cause the failure of one island, it is likely that other islands with the same or higher vulnerability would also fail. Thus, a strong earthquake affecting the study area could cause levee failures on several islands, and there is a real prospect of multiple islands flooding at the same time. For the seismic analysis, the highest, most likely water level that would exist both during and after an earthquake is the mean higher high water, as discussed in Section 7. Therefore, the islands included in the seismic analysis are those within the boundary of the MHHW, as shown in Figure 13-1. Figure 13-2 shows the annual frequency of exceeding a number of simultaneously flooded islands as a result of a seismic event in or in the vicinity of the Delta and Suisun Marsh. The figure shows the mean frequency of exceedance and the estimate of uncertainty calculated from the uncertainty in the ground motion hazard and the levee fragility uncertainties (which were discussed in more detail in Section 6 and in the Seismology Technical Memorandum (TM) [URS/JBA 2007a] and the Levee Vulnerability TM [URS/JBA 2008c]). Some key statistics from the figure are shown in Table 13-2.

If we take the specific case of 30 or more simultaneous island failures from Table 13-2, that outcome has about a 38 percent probability of being exceeded in an exposure period of 25 years.

Figure 13-3 shows the contribution of different seismic sources to the frequency distribution on flooded islands.

The 2005 base case results can be used to assess the probability of island flooding events in 2005 caused by a seismic event. These estimates assume existing (2005) conditions prevail; they do not consider the increasing hazard potential or the changes in levee vulnerability that may exist in the future. Figure 13-4 shows the probability of exceeding a number of simultaneous island failures due to seismic events for 25-, 50-, and 100-year exposure periods.

Each island was also analyzed individually to estimate its annual frequency of failure caused by seismic events. This analysis answers the question, "How likely is it that a given island will flood as a result of an earthquake?" It does not consider whether other islands are or are not flooded at the same time.

Table 13-3 presents the estimated annual frequency of failure for each island in the study area. The islands were grouped into five seismic risk categories for different ranges of frequency of failure. The ranges include less than 0.01/year, 0.01 to 0.03/year, 0.03 to 0.05/year, 0.05 to 0.07/year, and greater than 0.07/year. The results indicate that the island levees are highly vulnerable to seismic shaking. The study area has been grouped into three regions: Delta, Suisun Marsh, and Cache Slough. Of the 70 Delta islands/tracts analyzed (within the MHHW boundary), 11 have frequency of failure per year of less than 0.01, 39 islands have a frequency of failure per year of 0.01 to 0.03, and the remaining 20 islands have a frequency of failure per year of between 0.03 and 0.05. All islands/tracts analyzed in the Suisun Marsh area have a frequency of failure per year of 0.01 to 0.05. All islands/tracts within the Cache Slough region have a frequency of failure per year of less than 0.02. Figure 13-5 illustrates the number of islands within each range of mean failure rates.

Table 13-4 summarizes the contributions of all seismic sources to island failures. Figure 13-6 presents the percent contribution from the major seismic sources to the island failures by region, as explained by the examples discussed in the bullets below. Figure 13-7 presents a color-coded map showing the range of the annual failure frequency of individual islands caused by seismic events. The contributions from the different seismic sources for the three identified study regions are summarized as follows:

- **Delta**: Hayward fault: 16 percent; Calaveras fault: 10.5 percent; Southern Midland fault: 9.5 percent; San Andreas fault: 9.5 percent; Mt. Diablo blind thrust fault: 5.5 percent; CRSB fault zone: 5 percent; Northern Midland fault: 5 percent; Creek-Berryessa fault: 5 percent; and the remaining sources: 34 percent.
- **Suisun Marsh**: Concord-Greenville fault: 14.5 percent; Hayward fault: 14.5 percent; Calaveras fault: 5.5 percent; San Andreas fault: 4 percent; and the remaining sources: 61.5 percent. (Many other local faults contribute equally to the hazard in Suisun Marsh.)
- **Cache Slough**: Northern Midland fault: 17 percent; Hayward fault: 14 percent; CRSB fault zone: 9 percent; Southern Midland fault: 8 percent; Hunting Creek-Berryessa fault: 7.5 percent; San Andreas fault: 6 percent; and the remaining sources 38.5 percent.

A few faults contribute relatively equally to the seismic hazard in the Delta region. The Hayward fault is the highest contributor to the hazard in the Delta. The Hayward and Concord faults are the highest contributors to the hazard in Suisun Marsh, and the Hayward and Northern Midland faults are the highest contributors to the hazard in the Cache Slough area.

Unlike for sunny-day and hydrologic (flood) events, the predicted failure frequencies for seismic events cannot be compared directly to historical failure frequencies for several reasons. First, seismic events are infrequent and hence do not provide a sufficient number of data points to calculate reliable statistics on the average failure frequency. This point is particularly relevant for the Delta levees, which have only existed in their current configurations for about 50 years.

Second, the recurrence process of seismic events (seismicity) is dependent on past history. For example, the probability of an earthquake may increase after a “seismic gap”; that is, an extended period with no major earthquake (see Figure 13-8 for the period between 1906 and 1989 [WGCEP 2003]).

Because the Delta region has not experienced a major earthquake over the past 100 years, the probability of a major earthquake is higher now. The DRMS seismic hazard analysis incorporates time-dependent seismicity models. The recorded earthquake ground motions in the Delta region (expressed as peak ground acceleration [PGA]) since the levees have been in their current configurations have been less than 0.1g (more accurately, around 0.05g). However, the faults in this region are capable of generating earthquakes that could result in ground motions (PGAs) in excess of 0.3g. The fact that no ground motion greater than 0.1g has been experienced in the Delta region in the past 100 years does not mean that such an event could not occur in the future. In fact, if a time-dependent seismicity model were assumed to apply, the probability of such an event would be higher now than before.

For example, between 1838 and 1906 (68 years), three major earthquakes occurred in the Bay Area region of magnitude greater than 6.5 and more than a dozen of magnitude between 6.0 and 6.5. The period from 1906 to today (102 years) has been relatively quiet (as far as earthquakes with magnitudes higher than 6.5) except for the 1989 Loma Prieta earthquake. One can reasonably expect that the cycle of higher seismic activities could return, particularly considering the more recent seismic activities beginning in 1969 (see Figure 13-8) and considering the strain accumulation in the tectonic plates since 1906. If we return to the pre-1906 period, it is conceivable that two to three major earthquakes could occur in the region, as indicated in Figure 13-8.

### *Comparison with Other Seismic Risk Studies and Case Histories*

In the absence of historical events in the study area to compare with the results of this work, we compared the results of this work to relevant studies that others have done in the study area. Also, we compared the results of this work to available case histories outside the study area.

The CALFED study (CALFED 2000b) proved to be the most relevant past study for purposes of this comparison, because that study also analyzed the behavior of the Delta levees under seismic loading. Differences between the studies were established before the comparison was made. This allows the differences and similarities to be put in context.

- The CALFED study analyzed the frequency of levee failures, whereas the DRMS study analyzed the frequency of island failures (taking into account the possibility of multiple levee failures on any given island).
- The DRMS study used the most recent updates for both the seismic sources and the new attenuation relationships, as discussed in the Seismology TM (URS/JBA 2007a). Figure 6-21 in Section 6 presents a comparison of ground motions (PGAs for a 100-year return period) at six sites in the Delta and Suisun Marsh from the DWR 1992, CALFED 2000b, and DRMS studies. That comparison has shown that generally the ground motions are similar.
- The DRMS study used more than 2,000 boring logs, a number of cone penetration soundings, and downhole geophysical surveys to characterize the Delta and Suisun Marsh levee and foundation conditions. Because of the extensive data characterization, the geographic discretization of the project area extended down to multiple levee classes within each reach and multiple reaches within each island. The discretization was small enough to be able to represent the variation of levee fragilities within each island. The CALFED study relied on a coarser mesh of four sectors representing the Delta, which was appropriate for the scope and schedule allocated for that study.

The differences in the modeling details and the presentations of the results (levee breaches versus island failures) make it difficult to draw a one-to-one comparison of the results between the two studies.

Comparison of the study results with two case histories of known levee failures during past earthquakes were presented in Section 6. These two case histories included the 1995 Kobe, Japan, **M** 6.9 earthquake and the 1989 Loma Prieta **M** 6.7 earthquake. The Kobe earthquake represented the high ground motion benchmark, with a PGA at the levee site in Japan in excess of 0.5g. The Loma Prieta earthquake was more of a moderate ground motion benchmark, with an estimated PGA of 0.28g to 0.33g at the levee failure site along the Pajaro River in Watsonville, California. The observed deformations from these two cases were found to be consistent with the model results of this study, as discussed in Section 6.2.6.7.

The Delta has experienced low ground motions (PGAs of less than 0.1g) during small and recent earthquakes. No levee damage was reported during those small events. For the same ground motions, the response functions developed for the Delta in this study predict insignificant to no damage to the levees for the same events (see Section 6.2.6.7).

In summary, the calculated ground motions in DRMS are generally similar to those calculated in the CALFED 2000b study and the DWR 1992 study. Furthermore, the observed levee failures in the reported case histories are similar to the calculated deformations in this study for low, moderate, and high ground motions.

After completion of the levee response model to earthquake shaking, and the comparison with other studies and case histories, an analysis scenario was performed that considered an earthquake on the Hayward fault. The results of a simulated earthquake of **M** 7.2 on the Hayward fault are presented in Figure 13-9. The estimated mean number of island failures is about 50. The probability of 10 to 15 island failures is very high. Figure 13-9 presents estimates of the number of flooded islands resulting from a large earthquake on the Hayward fault. It should be recognized that many islands, though not flooded, will likely be damaged during a Hayward fault event and would need repair. The cost and duration of repairs are addressed in the consequences part in Section 13.3 for all outcomes from all events.

### 13.2.3 Hydrologic (Flood) Risk

Hydrologic events (floods) are major occurrences that can result in several islands flooding as a result of a single event. The expected number of simultaneous island failures under a large hydrologic event would be smaller than under a large earthquake event. However, hydrologic events (floods) are more frequent than earthquake events and would cumulatively cause more island failures over a long period. Figure 13-10 presents the frequencies of exceeding a number of simultaneous island failures due to a flood event. Figure 13-10 presents both the median frequency of exceedance and the uncertainties calculated from hazard and fragility functions (discussed in Section 7). Key statistics from Figure 13-10 are summarized in Table 13-5.

A comparison of flood events to seismic events indicates that 30 or more islands have about a 21 percent probability of being flooded under a single hydrologic event (Table 13-5), whereas the same number of islands would have about 38 percent probability of being flooded under a seismic event in 25 years (Table 13-2). However, the probability of a smaller number of simultaneous island failures occurring during hydrologic (flood) events is larger than for seismic events.

The 2005 base case results can be used to assess the probability of island flooding events in 2005 as a result of hydrologic events. These estimates assume that existing (2005) conditions prevail; they do not consider the increasing hazard potential or the changes in levee vulnerability that may exist in the future. The changing risk picture over time is discussed in Section 14. Figure 13-11 shows the probability of exceeding a number of simultaneous island failures due to hydrological events for 25-, 50-, and 100-year exposure periods. For simplicity, no uncertainty bounds are shown; they would be similar to the ones shown in Figure 13-10.

Each island was also analyzed individually to estimate its annual frequencies of failure as a result of flood events. For islands for which sufficient historical flooding data were available, the model-estimated failure frequency was compared to the observed failure frequency. Table 13-6 presents the results of individual islands' annual frequency of failure and the probability of at least one failure in 25-, 50-, and 100-year exposure periods.

The islands were then grouped into five flood risk categories for different ranges of annual frequency of failure. The ranges were as follows: less than 0.01/year, 0.01 to 0.03/year, 0.03 to 0.05/year, 0.05 to 0.07/year, and greater than 0.07/year, as shown in Figure 13-12. Figure 13-12 also shows the number of islands within each annual failure frequency range.

In a manner similar to that used in the seismic case, the study area has been grouped into three regions: the Delta, Suisun Marsh, and the Cache Slough area. The results from the flood risk analysis are considered separately to assess the performance of levees during and after flooding in these regions. The number of islands evaluated for the flood risk are those islands and tracts within the boundary of the 100-year flood zone, as shown in Figure 13-1. The number of islands analyzed for the seismic risk and the flood risk are consequently different.

Of the 93 Delta islands and tracts analyzed (number of islands within the 100-year flood zone), 45 islands have a frequency of failure per year of less than 0.01, 33 islands have a frequency of failure per year of between 0.01 and 0.03, 11 islands have a frequency of failure per year of between 0.03 and 0.05, and 4 islands have a frequency of failure per year of between 0.05 and 0.07. The islands/tracts in Suisun Marsh have a frequency of failure per year of greater than 0.07. The levee crest elevations in the Suisun Marsh area are generally lower than in the rest of the Delta and therefore prone to more frequent overtopping at low-return-period water stages. In a few locations, the Suisun Marsh levees have been lowered to allow tidal exchange. It should also be noted that the consequences of failures in Suisun Marsh are not as significant as those for the Delta. The islands/tracts in the Cache Slough area have a frequency of failure per year of less than 0.03. Figure 13-13a shows a color-coded map of the range of the annual failure frequency of individual islands caused by hydrologic (flood) events. Figure 13-13b shows a comparable map of historical flood failures in the Delta since 1900. It should be noted that no complete data set exists for Suisun Marsh.

### 13.2.4 Combined Risk of Island Inundation

Figure 13-14 shows the comparison of the mean frequency distributions on the number of flooded islands caused by the three initiating events (sunny-day, seismic, and flood events). Only the seismic and flood distributions show up on the figure. As indicated above, the annual frequency of multiple sunny-day failures is insignificant. As a result, normal sunny-day failures appear as a point in the figure. Key values from Figure 13-14 are summarized in Table 13-7 for the annual frequency of exceedance and three exposure periods (25, 50, and 100 years). It is worth noting from Figure 13-14 that the flood events produce higher frequency of failure up to 10 flooded islands, whereas the seismic events produce higher frequency of failures for more than 10 flooded islands. For example, the frequency of exceeding 3 flooded island is about 22 percent for flood events and 8 percent for seismic events (2.75 times higher). Whereas the frequency of exceeding 50 flooded islands is about 0.1 percent for flood events and 0.8 percent for seismic events (8 times higher).

Figure 13-15 presents the probability of exceeding various numbers of islands flooding due to any causes (sunny-day events, earthquakes, or floods). The figure presents probability of exceedance for the same three exposure periods (i.e., 25, 50, and 100 years).

The consulting team also combined the contributions of all hazards to calculate the overall risk of individual island flooding. Table 13-8 shows the aggregated risk for each island from all hazards combined. Figure 13-16 depicts the risk by island in the same five color-coded ranges used in the previous cases.

## 13.3 CONSEQUENCES

Any Delta levee failure has consequences—for public safety, the state economy, and the ecosystem. Potential consequences are discussed in detail in Section 12. Each island has its own assets and resources, as summarized in Section 12 and in the Impact to Infrastructure TM (URS/JBA 2007f). However, a single stressing event that could cause the simultaneous failure of levees on multiple islands and subsequent flooding of these islands may have much larger consequences than those associated with the failure and flooding of the individual islands involved. This section considers the range of potential consequences and, especially, the escalation of consequences in multi-island failure events.

### 13.3.1 Seismic Consequences

To estimate the consequences that would result from levee failures initiated by a seismic event, Monte Carlo simulations were performed to generate sequences of levee failure events. The simulations were conducted for the range of earthquake magnitudes and earthquake ground motions that could occur and the performance of Delta levees. For each sequence of levee failures and combinations of island flooding, the consequences in terms of loss of life due to flooding, the economic consequences, and ecological impacts were evaluated. All uncertainties associated with each variable in the sequences of levee failures were formally carried through the simulation, including the consequences when a probabilistic model was used (i.e., life losses).

Each sequence of levee failures defines the state of each levee and island in the Delta given the occurrence of an earthquake (see the discussion in Section 4). The first step in the consequence analysis is the assessment of the cost and timing of emergency levee repairs. Given the timing of the repairs, the hydrodynamic response of the Delta is evaluated to assess the extent of the salinity intrusion that occurs and the impact of the salinity on water quality. Because an earthquake can occur at any time of year or during any particular year (and thus at random during a hydrologic cycle), the hydrodynamic analysis also considers this randomness in the evaluation of hydrodynamic response of the Delta. Using the historical hydrologic record as a dataset, earthquake occurrence times (in terms of months of the year and hydrologic year) are simulated to generate random event start times. For sequence and random start time, the hydrodynamic performance of the Delta is evaluated.

The result of this series of hydrodynamic calculations is a distribution of water export deficits and durations of export disruptions. The distribution of deficits was used to select a series of sequences that served as input to the economic consequences analysis. The sequences that were selected correspond to the 0.05, 0.50, and 0.95 probability levels of the south-of-Delta deficit distribution. For purposes of evaluating the number of fatalities that could occur on flooded islands, the complete set of simulated sequences was used.

#### *13.3.1.1 Emergency Levee Response and Repair*

For the levee failure sequences that are evaluated, the cost and timing of emergency levee repairs were evaluated. The range (mean plus and minus one standard deviation) of the costs of levee repairs and the timing of dewatering for various numbers of flooded islands are shown in Table 13-9. These results are based on the repair of seismically initiated levee breaches, the repair of non-breach damage on both flooded and non-flooded islands, and the repair of interior levee slope erosion damage on flooded islands.

For a 20-island breach event, the total cost of levee repair and dewatering would be about $1.8 billion on average, with a range of $1.4 to $2.3 billion. Repair would require 25 months on average, with a range of 20 to 30 months from the date of the earthquake. Dewatering of all the islands would occur about 29 months after the earthquake on average, with a range of 25 to 34 months. Repairs for 30 flooded islands could approximately double these cost and duration numbers.

#### *13.3.1.2 Export Disruption*

When levee failures occur during the late spring, summer, or early fall, saline water from Suisun Bay will be drawn into the Delta and onto flooded islands. Water might not be of adequate quality for use by the state and federal water projects, the Contra Costa Water District, or in-Delta users. Pumping may be disrupted for a relatively short period or for longer durations, depending on the levee failure sequence (the number and location of the islands that are flooded).

Figure 13-17 illustrates the variation in the duration of no water exports for levee sequences involving 3 and 20 flooded islands. The graphs in the figure show the cumulative distribution functions that quantify the variability in the duration of no water exports due to the variability in the combination of islands that are flooded (given that 3 or 20 islands are flooded, respectively) and the variation in the month of occurrence and in the hydrologic conditions that exist at the time of the earthquake. Figures 13-17a and 13-17c show the results when a single hydrologic start time is considered (month of the year and hydrologic condition). This so-called Normal hydrology was selected from the distribution of hydrodynamic calculations for a 30-breach case in which over 900 start times were considered (these start times are derived from the 55-year hydrologic record for California). The Normal hydrology corresponds to the median of the distribution of hydrologic start times. The results in Figures 13-17a and 13-17c suggest a considerable amount of variability due to the mix of islands that are flooded in a sequence. As expected, the duration of no exports is greater in the 20-island case than in sequences involving only 3 islands.

The cumulative distribution functions for the “Varied” hydrology case consider the same combination of flooded island sequences for each case (the 3- and 20-island cases in Figures 13-17b and 13-17d), with the addition of the variability due to hydrologic start times. In these cases, 3 hydrologic conditions were considered corresponding to the 0.05, 0.50, and the 0.95 probability levels of the distribution of 900 hydrologic start times (as described above). A comparison of the results for the Normal and the Varied hydrologic cases show the increased variability in the duration of no exports when the variation in hydrologic conditions is considered.

Figure 13-18 shows a similar set of results for the same simulations when the size of the south-of-Delta delivery deficits is considered. The disruptions shown in Figures 13-17 and 13-18 consider only salinity intrusion sufficient to make Delta waters unusable for both urban and agricultural contractors.

After pumping resumes, water may need additional treatment to satisfy drinking water standards. The primary contaminant of concern is organic carbon, which may react with disinfectants to produce byproducts that are carcinogenic. Preliminary analyses performed as part of the DRMS project indicate that some water may not be treatable by municipal agencies for many months, thereby extending the period that Delta supplies may be unavailable to urban users. Costs of additional treatment, when feasible, could be as much as $70 million (see Section 12.2). As such, careful management of island dewatering would be needed to avoid high concentrations of organic carbon. More detailed water quality modeling is needed to better analyze these treatability issues.

#### *13.3.1.3 Economic Consequences of Earthquakes*

As described in Section 12, economic consequences were quantified in terms of *economic costs* and *economic impacts*. The economic costs are the net costs to the state economy without consideration of who bears the cost. All economic costs are generally additive. Economic impacts include a variety of other economic measures. For this study, four measures of economic impacts were evaluated: the value of lost output, lost jobs, lost labor income, and lost value added. Value added is the sum of wages and salaries, proprietors' incomes, other property income, and indirect business taxes. These measures are not additive with each other, and they should not be added to economic costs.

##### *Seismic Economic Case Study Results*

The analysis for seismic events evaluated the economic consequences for a range of levee failure sequences that were simulated. As discussed previously with respect to the hydrodynamic response of the Delta to seismic sequences, the outcome of a sequence in terms of the economic consequences depends strongly on the nature of the levee failure sequence (the number and the specific islands that have flooded), the time of year that the earthquake occurs, and the hydrology at the time of the event.

Economic costs are summarized in terms of two broad categories: in-Delta costs and state-wide costs, as shown in Table 13-10a. The main elements of in-Delta costs are emergency response and repair costs, infrastructure repair costs, lost use of structures and services, agricultural losses, and lost recreation. About 30–40 percent of in-Delta costs are attributed to the cost of levee emergency response and repair, 40–50 percent of these costs are due to damage to infrastructure, including residences and businesses, and 10–15 percent of these costs are from lost recreation. The distribution of in-Delta costs varies considerably, depending on the islands that are flooded and the number of islands involved in a sequence.

The main elements of state-wide costs are agricultural losses, urban user losses due to water supply disruption, and the lost use of major infrastructure (e.g., state highways that cross the Delta). Because the In-Delta cost and Statewide cost are not perfectly correlated, the percentiles of the two costs cannot be theoretically added to obtain the corresponding percentile of the total cost. However, the two costs are highly correlated and hence the sum of the percentiles of two costs is a reasonable approximation of the same percentile of the total cost. For simplicity, the percentiles of the total cost in Table 13-10a were calculated by adding the corresponding percentiles of the In-Delta and Statewide costs.

The economic impacts are mostly controlled by the value of lost output, followed by lost value added, and then lost labor income, as shown in Table 13-10b for a range of sequences of flooded islands. The lost jobs are also shown in the same table.

For sequences that involve water supply disruption, the variation in the total state-wide costs can be as much as 100 percent for sequences involving the same number of flooded islands. For a given number of flooded islands, this variability is about 70 percent from urban user loss due to water supply disruption and about 30 percent from lost use of major infrastructure.

### *Seismic Economic Risk Results*

The economic costs and impacts were evaluated and combined with the frequency of occurrence of each sequence. The results are shown in Figures 13-19a and 13-19b in terms of the annual frequency of exceeding various economic costs and impacts and their uncertainties due to seismic events, respectively.

### *13.3.1.4 Ecological Consequences from Earthquakes*

The conceptual model developed for the effects of levee failures on sensitive aquatic species, vegetation, and terrestrial wildlife provides a framework for a qualitative risk assessment, incorporating both the beneficial and the adverse effects associated with levee failures. The impacts to aquatic species, vegetation, and terrestrial wildlife are presented in Tables 13-11 through 13-25. The ecological impacts of five different seismic levee-failure scenarios were assessed. The scenarios involved levee failures on as few as 2 islands and as many as 30 islands. Each scenario was analyzed for three different water years: a spring wet year (represented by 1927 conditions), a summer average water year (represented by 1930), and a fall dry water year (represented by 1972).

### *Aquatic Species*

As indicated in Section 12 and in the Impact to Ecosystem TM (URS/JBA 2008e), the aquatic model was developed through formal expert elicitation, as recommended by the DRMS Independent Review Panel (IRP). The work developed so far has focused on evaluation of potential short-term impact mechanisms, including levee-failure-induced fish entrainment, increased turbidity during breach events, saltwater effects, pump-out of flooded islands, export interruptions during levee failure events, and the potential for new habitat development in the flooded islands. The model was also constructed to accommodate uncertainties and provide probabilities and estimates of uncertainties on losses of different species and life stages as well as the probable extinction of species.

Because of limited time and the limited availability of experts, the model was not fully developed. The model was not fully executed for the production runs, and therefore the consequences on the aquatic species are not available at this stage.

### *Vegetation*

The impacts to vegetation types and terrestrial species are shown as a percentage of vegetation or habitat area impacted. As discussed here, vegetation types do not include agricultural land, but agricultural land is incorporated into impacts on terrestrial species.

In all seismic levee-failure scenarios, the extent of impacts to habitat increased with area flooded, but the magnitude of the impacts depended on the vegetation type. For example, losses of up to 39 percent were forecasted for herbaceous wetland seasonal ruderal habitat, 29 percent for non-native trees, and 24 percent for shrub wetland in the Delta and Suisun Marsh. Of critical vegetation types that harbor native vegetation and rare species of vegetation, native herbaceous upland (which constitutes a small total area of the Delta [less than 500 acres]) was not affected by flooding in any of the cases. Less than 12 percent of critical intertidal and aquatic habitat was affected in any scenario; however, shrub wetland lost 24 percent of its total habitat in the Delta and Suisun Marsh in the worst case. Overall, these results, though not incorporating the impacts of levee breaches on sensitive species, suggest that primary impacts of flooding are on non-native species of vegetation. However, a considerable amount of critical habitat including alkali high marsh, shrub wetland, and riparian trees are reduced by 10 to 24 percent.

For breach scenarios involving less than 10 breaches, very small percentages (0 to 8 percent, average 1 percent) of the total area of the vegetation types in the Delta and Suisun Marsh are impacted, with the greatest impact on non-native upland trees (7 percent). In the 10-breach scenario, impacts to more than 10 percent of the total area are seen in herbaceous ruderal upland (17 percent) and herbaceous wetland seasonal ruderal (23 percent), shrub wetland (10 percent), and non-native upland trees (14 percent).

In the 20-breach scenario, greater losses in area are seen for each vegetation type affected in the 10-breach scenario (herbaceous ruderal upland (23 percent of the total area), herbaceous wetland seasonal ruderal (33 percent), shrub wetland (18 percent), non-native upland trees (15 percent), riparian trees (12 percent), with an additional loss of less than 10 percent for riparian trees. In the 30-breach scenario, alkali marsh lost about 11 percent of its total area, herbaceous ruderal upland about 30 percent, herbaceous wetland seasonal ruderal about 39 percent, shrub wetland about 24 percent, and non-native upland trees about 29 percent, with the exception of riparian trees about 17 percent.

In the 20-breach scenario, greater losses in area are seen for each vegetation type affected in the 10-breach scenario (herbaceous ruderal upland [23 percent]), herbaceous wetland seasonal ruderal [33 percent], shrub wetland [18 percent], non-native upland trees [15 percent], riparian trees [12 percent], with the additional loss of less than 10 percent of riparian trees). In the 30-breach scenario, alkali marsh lost about 11 percent of its total area, with the following distribution by subcategory of species: herbaceous ruderal upland (30 percent) and herbaceous wetland seasonal ruderal (39 percent), shrub wetland (24 percent), and non-native upland trees (29 percent), with the exception of riparian trees (17 percent).

### *Terrestrial Wildlife*

The breaching of Delta levees resulted in no impacts to several terrestrial wildlife species of concern whose habitats are restricted to Suisun Marsh (including the federally endangered saltmarsh harvest mouse, saltmarsh common yellowthroat, California clapper rail, and Suisun ornate shrew). In contrast, large numbers of the levee breaches modeled would affect 32 percent of available habitat for sandhill cranes and 42 percent of available habitat for waterfowl. These estimates could over- or underestimate the impacts on these birds, because it was assumed that all agricultural land was habitat and that the loss of agricultural land resulted in a proportional loss of habitat. In actual fact, these birds use only a fraction of agricultural land (grains, pasture alfalfa, corn, and rice).[1] Nevertheless, the results suggest that large-scale levee breaches may cause substantial losses of available habitat, and depending on whether food is limited or plentiful in the available habitat, these habitat losses could cause food shortages and displace birds.

#### *13.3.1.5 Public Health and Safety Consequences From Earthquakes*

The primary public safety concern is the potential for loss of life on islands that are flooded as a result of a seismic event. The analysis and procedure used to calculate probable life losses is described in Section 12 of this report. Under seismic conditions, a full simulation was conducted for each fault, each magnitude, all combinations of multiple numbers of flooded islands, and for each island's conditional probability of loss of life. All uncertainties associated with each variable in the sequence were formally carried through the simulation. Figure 13-20 shows the mean frequencies of exceeding different numbers of fatalities due to seismic events. For example, the mean frequency of 10 or more fatalities is about 0.01 and the mean frequency of 100 or more fatalities is 0.002.

### 13.3.2 Flood Consequences

As in the case for seismic events, sequences of flood-initiated levee failures and island flooding sequences were simulated for the range of floods modeled in the risk analysis. The range of flood events varies from 289,000 cubic feet per second (cfs) total Delta inflow to nearly 2 million cfs. These potential inflows are higher than those that have been experienced to date. Based on preliminary flood vulnerability results, inflows larger than the 100-year flood can be expected to cause a significant number of failures and consequent island flooding.

For each simulated sequence, the emergency response and repair analysis was carried out and the economic consequences were evaluated. No non-breach damage to levees was assumed and only one breach was modeled per island.

#### *13.3.2.1 Emergency Levee Response and Repair*

The cost and duration of emergency levee repairs as a result of flood-initiated levee failures are shown in Table 13-26. The cost of repairs is less than that required for seismically initiated levee failures (for the same number of flooded islands) because of the more extensive damage caused by earthquakes. Emergency repairs are estimated to cost about $580 million to restore 10 simultaneously flooded islands, with a range of between $490 and $680 million. Also, it will take about 2 years to repair 10 flooded islands, and about 6 years to repair 30 flooded islands (see Section 10 and the Emergency Response and Repair TM [URS/JBA 2008d] for a discussion of the emergency response model and the assumptions used in the analysis).

[1] A crop map was not available for this analysis.

During flood events, high Delta inflows of freshwater will prevent the inflow of salty water into the Delta as islands flood. As a result, little to no impact to water export will occur as a result of levee failures that are initiated by hydrologic events (see the discussion in Section 4).

#### *13.3.2.2 Economic Consequences of Floods*

##### *Flood Economic Case Study Results*

The economic costs and impacts associated with levee failures that occur as a result of a flood event are different in a number of respects from those associated with seismically initiated levee failure sequences. These differences include the following:

- Seismic events cause non-breach damage on both flooded and non-flooded islands, whereas non-flooded islands are not damaged as a result of a hydrologic event.
- In the seismic analysis, the consulting team considered 76 analysis zones (islands and tracts) located within the MHHW boundary, excluding Suisun Marsh. In the flood analysis, 93 analysis zones (islands and tracts) were considered within the 100-year flood boundary. The 100-year flood boundary is larger than the MHHW boundary.
- The Delta islands that are vulnerable to hydrologic events differ in a number of respects from the islands that are vulnerable to seismic events. For one thing, the islands included in the flood analysis but not in the seismic analysis have (quite obviously) a different vulnerability to these hazards. Also, for islands that are considered in both analyses, on an island-by-island basis levees have different degrees of vulnerability to the different hazards. As a result, the levee failure sequences that can occur during hydrologic events may be different than the sequences that occur during seismic events.
- The distribution of peak flood elevations will be different than the distribution of earthquake ground motions for a given event. For instance, the majority of the inflow to the Delta occurs in the Sacramento-Yolo system. As a result, the islands in this part of the Delta will see higher peak flood elevations during a given flood event than other parts of the Delta. In the case of seismic events, strong earthquake ground motions may be experienced over all or large parts of the Delta. As a result, the differences in the spatial patterns of these hazards result in the flooding of different combinations of islands for the two types of hazards.
- A number of islands that are included in the hydrologic risk analysis and not in the seismic analysis are areas that have (relatively) high populations and developed infrastructure (residences and businesses).
- As discussed in Section 4, flood-related failures are unlikely to have water export impacts. As a result, the statewide impacts are not as great as those for seismic-related failures, all other factors being equal.
- When a seismic event occurs, 1 to 3 breaches may occur on an island that floods. In the case of a hydrologic event, only one breach occurs per flooded island.

When a seismic event occurs, the results of the seismic analysis indicate that non-breach damage can involve many tens of thousands of feet of levee. This damage involves additional repair costs. This damage also has additional downstream impacts on the amount of erosion damage that occurs on island levee interiors as they await repair and protection and on the period of disruption to island businesses and residents awaiting island repair and dewatering.

Tables 13-27a and 13-27b summarize the range of economic costs and economic impacts, respectively, for sequences of flood-initiated levee failures. Again, economic costs are summarized in terms of two broad categories: in-Delta costs and state-wide costs. As noted previously, for simplicity, the percentiles of the total cost in Table 13-27a were calculated by adding the corresponding percentiles of the In-Delta and Statewide costs. For a small number of flooded islands, the in-Delta costs dominate the total costs; however, for the larger number of flooded islands, the state-wide costs are approximately double those of the in-Delta costs. The main elements of in-Delta costs are the emergency response and repair costs, the infrastructure repair costs, the costs due to loss of use of structures and services, the costs of agricultural losses; and the costs of lost recreation. About 15 to 20 percent of in-Delta costs are from the emergency response and repair and the infrastructure repair, and 60 to 70 percent of the costs are from loss of use of structures and services. Other significant in-Delta costs are caused by loss of recreation and agricultural damage, corresponding to about 10 to 25 percent. The main state-wide infrastructure disruption is to the disruption of Delta area highways.

### *Flood Economic Risk Results*

The economic costs and impacts were evaluated and combined with the frequency of occurrence of each sequence. The results are shown in Figures 13-21a and 13-21b as the probability of exceeding various economic costs and impacts, respectively, and their uncertainties due to flood events.

Although the total economic cost of a given number of flooded islands is similar for seismic and flood events, the frequency of a large number of islands flooding is much higher for seismic events. The overall risk for each hazard is calculated by combining the frequencies and consequences of different numbers of flooded islands. This risk is expressed in terms of the frequency of exceeding different amounts of the total economic cost. The results are shown in Figures 13-19b and 13-21b, respectively for seismic and flood hazards. As seen in these figures, the risk is much higher for seismic events than flood events. For example, the annual frequency of exceeding a total cost of $ 40 billion is about 1 percent for seismic events and 0.3 percent for flood events.

The overall economic impacts of a given number of flooded islands are higher for flood events than seismic events. The two main contributors to the economic impacts are the loss of structures/services and water export disruption.

The impacts of loss of structures and services are higher for floods because all analysis zones within the 100-year flood boundary are considered. In contrast, only the analysis zones within the MHHW boundary are considered for the seismic events. Some of the zones with high population and infrastructure, such as the Sacramento Pocket Area, are outside the MHHW, but within the 100-year flood boundary.

On the other hand, the impacts of water export disruption are incurred only for seismic events and are negligible for flood events. However, the economic impacts of water export disruption depend on many factors, including the types of past, current, and future of hydrological years and the season. These impacts are relatively low for a large proportion of the sequences of flooded islands, for example, sequences in the north of the Delta will have minimal impacts on water exports. The average value of lost output for a sequence of 30 flooded islands is about $ 1 billion. In contrast, the average value of lost out due to loss of structures/services for the same sequence is about $6 billion for flood events and about $2 billion for seismic events. The net effect of water export disruption and loss of structures/services on the value of lost output is an increase of $3 billion for flood events.

#### *13.3.2.3 Ecological Consequences of Floods*

##### *Aquatic Species*

See Section 13.3.1.4 for discussion of the aquatic species impact model.

##### *Vegetation*

In the flood scenarios, the breached islands are primarily in the northern Delta, in contrast with seismic levee-breach scenarios, in which the breached islands are primarily in the western, central, and southern Delta. This shift in geography results in vastly different impacts associated with flood-induced breach scenarios relative to seismic-induced breach scenarios. The primary difference lies in the greater loss of all tree vegetation for the flood scenarios evaluated. For example, for the 20- and 30-breach scenarios, the damage by vegetation type is respectively as follows: native trees (34 percent, 45 percent), non-native trees (22 percent, 35 percent), and tree wetlands (19 percent, 21 percent). Flood scenarios also result in extremely large losses of total critical native tree habitat, which, in contrast, is diminished by less than 10 percent of its total area in a seismic failure. Herbaceous upland, which composes the largest percentage of impacted areas in the seismic scenarios with large numbers of breaches, lost only 9 percent and 13 percent of total area in 20- and 30-breach scenarios, respectively. Smaller percentage losses in total habitat (less than 10 percent) in the Delta and Suisun Marsh are seen for all other vegetation types, which lose large areas (more than 10 percent) in seismic events.

##### *Terrestrial Wildlife*

In contrast with vegetation, little difference occurred in the impacts associated with the seismic- and flood-induced levee-breach scenarios. Neither flood nor seismic breach scenarios in Suisun Marsh impact the several terrestrial wildlife species of concern whose habitats are restricted to Suisun Marsh. These species include the federally endangered saltmarsh harvest mouse, saltmarsh common yellowthroat, California clapper rail, and Suisun ornate shrew.

As in the seismic levee breaches, the impacts of flood levee breaches include large losses of total habitat for sandhill cranes (for the 20-breach scenario, 34 percent; for the 30-breach scenario, 57 percent) and waterfowl (for the 20-breach scenario, 22 percent; for the 30-breach scenario, 36 percent). However, a flood-induced 30-island flood scenario almost doubles the loss of sandhill crane foraging habitat (57 percent) compared with a seismically induced 30-island flooding scenario (32 percent).

#### *13.3.2.4 Public Health and Safety Consequences from Floods*

Similar simulations to those of the seismic events were conducted for the flood events (Sec.13.3.1.5). Detailed discussion of the methodology and the calculations of the conditional probabilities of loss of life under flood conditions is presented in Section 12. The primary public safety concern is the potential loss of life associated with hydrologic events that cause levee failures and island flooding. Figure 13-22 shows the mean frequencies of exceeding different numbers of fatalities as a result of hydrologic events. For example, the mean frequency of 10 or more fatalities is about 0.12, and the mean frequency of 100 or more fatalities is about 0.01.

Although no fatalities have been recorded in the past 50 years or so as a result of levee failures from flood events within the Delta, levee failures and the subsequent flooding caused multiple fatalities in Northern California during floods in 1955 and 1997. Many variables affect the risk of fatalities due to flooding, including the proximity of population to the levee where a breach occurs, the time of day when the flooding happens, the amount of time elapsed after the event when warnings are issued, the amount of time available for evacuation, and the availability of safe evacuation routes. With only slightly different conditions, some of the historical levee failures during flood events within the Delta could have resulted in fatalities. It should also be noted that the loss-of-life risk has increased in recent years because of the rapid growth of housing closer to areas behind levees that were built to protect farmland. Given these factors, the mean annual frequency of 0.12 for events in the Delta causing 10 or more fatalities may be considered to be a realistic, perhaps somewhat conservative, estimate.

### 13.3.3 Sunny-Day Failure Consequences

Sunny-day failures are assumed to occur one island at a time. Consequences are expected to be similar to the single-island consequences of floods or earthquakes. Because sunny-day failures are defined to occur in the late spring, summer, or early fall (i.e., during the low-flow season), some possibility of salinity intrusion and Delta salinity/water export impacts were thought possible. However, as discussed in Section 4, both historical experience and hydrodynamic sensitivity calculations indicate that single-island failures will not have any impact or will have minimal impact (water export disruptions of 3 months or less; see the discussion in Section 4). For instance, a single-island failure for Brannon-Andrus was considered for all months in the CalSim trace (984 months as different event start times) and no significant impact on water exports was found. The maximum disruption was less than 3 months, with negligible economic impacts.

## 13.4 2005 BASE CASE RESULTS SUMMARY

The 2005 base case shows considerable potential for the Delta and Suisun Marsh areas to face a high risk of multiple-island failures from both seismic and flood events. The population at risk and the economic and ecological consequences of a major event can be severe in some cases. Aside from the number of islands that flood in a sequence, the economic consequences of a sequence will depend on three primary factors: which islands have flooded, the month in which the initiating event occurs, and where that month is in the hydrologic cycle.

The assumptions and limitations associated with this work are discussed in Section 15. The executive summary provides an overall summary of the key findings and observations.

Table 13-1 Delta and Suisun Marsh Annual Frequency of Sunny-Day Failures

| URS_ID | URS Name | Levee Length (Miles) | Annual Mean No. of Failures |
|---|---|---|---|
| 4 | Webb Tract | 12.9 | 1.18E-03 |
| 5 | Empire Tract | 10.5 | 9.56E-04 |
| 6 | Bradford Island | 7.4 | 6.77E-04 |
| 7 | King Island | 9.1 | 8.28E-04 |
| 9 | Jersey Island | 15.5 | 1.41E-03 |
| 10 | Bethel Island | 11.5 | 1.05E-03 |
| 11 | Quimby Island | 7.0 | 6.40E-04 |
| 12 | McDonald Tract | 13.7 | 1.25E-03 |
| 13 | Holland Tract | 11.0 | 1.00E-03 |
| 14 | Dutch Slough West | 1.8 | 1.68E-04 |
| 15 | Bacon Island | 14.3 | 1.31E-03 |
| 16 | Palm Tract | 7.9 | 7.19E-04 |
| 17 | Jones Tract-Upper and Lower | 18.7 | 1.70E-03 |
| 19 | Woodward Island | 8.9 | 8.14E-04 |
| 20 | Orwood Tract | 8.6 | 7.83E-04 |
| 21 | Victoria Island | 15.0 | 1.37E-03 |
| 32 | Coney Island | 5.5 | 4.99E-04 |
| 62 | Walnut Grove | 2.9 | 2.63E-04 |
| 63 | Tyler Island | 22.9 | 2.09E-03 |
| 75 | N. of Glanville Tract | 6.2 | 5.63E-04 |
| 77 | Elk Grove SE (Zones not in MHHW) | 1.4 | 1.31E-04 |
| 78 | Elk Grove Sth | 6.1 | 5.54E-04 |
| 86 | Terminous East | 1.3 | 1.23E-04 |
| 87 | Terminous | 19.2 | 1.75E-03 |
| 108 | Hotchkiss Tract | 6.7 | 6.08E-04 |
| 109 | Dutch Slough East | 2.0 | 1.86E-04 |
| 112 | Union Island East | 3.4 | 3.08E-04 |
| 113 | Union Island South East | 4.3 | 3.97E-04 |
| 114 | Stark Tract | 5.1 | 4.66E-04 |
| 115 | Upper Roberts Island | 17.8 | 1.62E-03 |
| 117 | Union Island | 25.3 | 2.31E-03 |
| 118 | Pescadero | 9.0 | 8.24E-04 |
| 119 | Paradise Junction | 7.0 | 6.40E-04 |
| 120 | McMullin Ranch | 10.2 | 9.33E-04 |
| 121 | Kasson District | 3.8 | 3.49E-04 |
| 126 | Pico Naglee Tract | 10.1 | 9.18E-04 |
| 127 | Byron Tract | 9.8 | 8.94E-04 |
| 129 | Veale Tract 1 | 5.4 | 4.91E-04 |
| 135 | West Sacto 1 | 10.8 | 9.88E-04 |
| 141 | Merritt Island | 17.7 | 1.62E-03 |
| 143 | Rindge Tract | 15.8 | 1.44E-03 |
| 144 | Mandeville Island | 14.3 | 1.31E-03 |
| 146 | Sutter Island | 12.4 | 1.13E-03 |
| 147 | Grand Island | 28.3 | 2.58E-03 |
| 148 | Elk Grove SW | 7.4 | 6.78E-04 |
| 149 | Pierson Tract | 15.9 | 1.45E-03 |
| 150 | Venice Island | 12.4 | 1.13E-03 |
| 152 | Medford Island | 5.9 | 5.37E-04 |
| 153 | Rough and Ready Island | 6.8 | 6.21E-04 |
| 157 | Smith Tract | 5.8 | 5.28E-04 |
| 158 | Weber Tract | 3.8 | 3.45E-04 |
| 159 | Boggs Tract | 6.1 | 5.56E-04 |
| 162 | Fabian Tract2 | 3.1 | 2.84E-04 |
| 163 | Fabian Tract | 18.8 | 1.71E-03 |
| 165 | Walthal Tract | 6.2 | 5.70E-04 |
| 166 | RD 17 (Mossdale) | 15.8 | 1.44E-03 |
| 168 | Libby McNeil Tract 1_2 | 3.7 | 3.39E-04 |
| 169 | McCormack Williamson Tract | 8.7 | 7.96E-04 |
| 170 | Glanville Tract | 11.5 | 1.05E-03 |
| 171 | Cosumnes River Area | 6.8 | 6.17E-04 |
| 172 | New Hope Tract | 13.6 | 1.24E-03 |
| 173 | Deadhorse Island | 2.6 | 2.36E-04 |
| 174 | Staten Island | 25.3 | 2.31E-03 |
| 175 | Canal Ranch | 10.6 | 9.66E-04 |
| 176 | Brack Tract | 10.8 | 9.87E-04 |
| 177 | Bouldin Island | 17.9 | 1.63E-03 |

Table 13-1 Delta and Suisun Marsh Annual Frequency of Sunny-Day Failures

| URS_ID | URS Name | Levee Length (Miles) | Annual Mean No. of Failures |
|---|---|---|---|
| 179 | Twitchell Island | 11.9 | 1.08E-03 |
| 182 | Shin Kee Tract | 6.5 | 5.97E-04 |
| 183 | Rio Blanco Tract | 5.8 | 5.31E-04 |
| 185 | Atlas Tract East | 1.6 | 1.47E-04 |
| 187 | Shima Tract | 7.0 | 6.42E-04 |
| 190 | Wright-Elmwood Tract | 7.1 | 6.44E-04 |
| 191 | Sargent Barnhart Tract | 7.9 | 7.19E-04 |
| 196 | Sacramento Pocket Area | 15.7 | 1.44E-03 |
| 197 | Elk Grove West | 7.4 | 6.76E-04 |
| 210 | Ryer Island | 20.2 | 1.85E-03 |
| 212 | Clifton Crt FW | 7.8 | 7.15E-04 |
| 216 | Fabian Tract South West 1 | 2.0 | 1.80E-04 |
| 1000 | Netherlands | 41.8 | 3.81E-03 |
| 1002 | Drexler Tract | 9.2 | 8.38E-04 |
| 1003 | Roberts Island | 29.6 | 2.70E-03 |
| 1004 | West Sacto 2 | 12.6 | 1.15E-03 |
| 1005 | Elk Grove | 17.4 | 1.59E-03 |
| 1006 | Upper Andrus Island | 11.2 | 1.02E-03 |
| 1007 | Lower Andrus Island | 29.9 | 2.72E-03 |
| 1008 | Stewart Tract | 12.2 | 1.11E-03 |
| 1009 | Mossdale R.D. No. 2107 | 5.7 | 5.16E-04 |
| 1010 | Clifton Crt FS | 5.2 | 4.70E-04 |
| 1012 | Atlas Tract | 3.0 | 2.72E-04 |
| 1013 | Bishop Tract | 8.7 | 7.90E-04 |
| 1014 | McMullin Rch2 River Junction Tr | 9.3 | 8.46E-04 |
| 1015 | Sherman Island | 19.4 | 1.77E-03 |
| 1016 | Smith Tract - Lincoln Village Tr | 5.6 | 5.07E-04 |
| 68 | Little Egbert Tract | 10.3 | 9.44E-04 |
| 70 | Egbert Tract Includes 69 | 5.4 | 4.89E-04 |
| 72 | Peter Pocket | 7.5 | 6.88E-04 |
| 79 | Peter's Pocket West | 3.8 | 3.49E-04 |
| 80 | Cache Haas Tract 1 East | 2.1 | 1.88E-04 |
| 88 | Cache Haas Tr1 | 8.9 | 8.16E-04 |
| 89 | Cache Haas Tr2 | 7.2 | 6.57E-04 |
| 1001 | Hastings Tract 81_82 | 17.1 | 1.56E-03 |
| 39 | SM-39 | 4.3 | 7.21E-04 |
| 40 | SM-40 | 5.7 | 9.49E-04 |
| 41 | SM-41 | 2.6 | 4.37E-04 |
| 42 | SM-42 | 1.5 | 2.41E-04 |
| 43 | SM-43 | 4.7 | 7.78E-04 |
| 44 | SM-44 | 6.1 | 1.01E-03 |
| 45 | SM-45 | 3.0 | 4.97E-04 |
| 46 | SM-46 | 4.1 | 6.73E-04 |
| 47 | SM-47 | 4.5 | 7.53E-04 |
| 48 | SM-48 | 12.1 | 2.00E-03 |
| 49 | SM-49 | 8.0 | 1.33E-03 |
| 50 | SM-1/2_50_58 | 20.2 | 3.35E-03 |
| 51 | SM-51 | 5.2 | 8.60E-04 |
| 54 | SM 54a | 7.6 | 1.26E-03 |
| 55 | SM-55_56_84_85_131_132 | 31.6 | 5.25E-03 |
| 59 | SM-59a | 6.2 | 1.02E-03 |
| 60 | SM-60 | 14.1 | 2.33E-03 |
| 123 | SM-123 | 8.3 | 1.37E-03 |
| 124 | SM-57_124 | 9.9 | 1.64E-03 |
| 133 | SM-133_134 | 8.9 | 1.48E-03 |
| 198 | SM-198 | 9.5 | 1.57E-03 |
| 201 | Honker Bay Club_Van Sickle Island | 15.0 | 2.49E-03 |
| 202 | SM-202 | 4.7 | 7.85E-04 |
| 203 | Simmons-Wheeler Island_SM-204 | 9.9 | 1.63E-03 |
| 54b | SM 54b | 5.3 | 8.79E-04 |
| 59b | SM-59b | 4.2 | 6.91E-04 |

Notes: The expected annual frequencies of historical sunny-day breaches are about $1.06 \times 10^{-4}$ failures/year/levee mile or 0.0969 failures/year in the Delta, and $4.76 \times 10^{-4}$ failures/year/levee mile or 0.036 failures/year in Suisun Marsh.

**Table 13-2 Annual Frequencies of Exceeding *N* Simultaneous Island Failures as a Result of Earthquake Event**

| Number of Islands (N) | Annual Frequency of Exceedance | Probability of Exceedance in 25 Years [a] | Probability of Exceedance in 50 Years [a] | Probability of Exceedance in 100 Years [a] |
|---|---|---|---|---|
| 1 | 0.107 | 0.931 | 0.995 | 1.000 |
| 3 | 0.082 | 0.872 | 0.984 | 1.000 |
| 10 | 0.051 | 0.723 | 0.923 | 0.994 |
| 20 | 0.032 | 0.546 | 0.794 | 0.958 |
| 30 | 0.019 | 0.383 | 0.620 | 0.855 |

[a] Assumes no changes in risk in future years. The effects of the changing risks in future years are discussed in Section 14.

Table 13-3 Delta and Suisun Marsh Individual Island Rates of Seismic Failures

| URS_ID | URS Name | Annual Mean No. of Failures | Probability of Failure in 25 years | Probability of Failure in 50 years | Probability of Failure in 100 years |
|---|---|---|---|---|---|
| 127 | Byron Tract | 4.41E-02 | 67% | 89% | 99% |
| 1006 | Upper Andrus Island | 4.26E-02 | 66% | 88% | 99% |
| 1007 | Brannan-Andrus Island | 4.26E-02 | 66% | 88% | 99% |
| 63 | Tyler Island | 4.20E-02 | 65% | 88% | 99% |
| 1002 | Drexler Tract | 4.20E-02 | 65% | 88% | 98% |
| 1003 | Roberts Island | 4.20E-02 | 65% | 88% | 98% |
| 21 | Victoria Island | 4.18E-02 | 65% | 88% | 98% |
| 10 | Bethel Island | 3.73E-02 | 61% | 85% | 98% |
| 9 | Jersey Island | 3.73E-02 | 61% | 85% | 98% |
| 1015 | Sherman Island | 3.67E-02 | 60% | 84% | 97% |
| 19 | Woodward Island | 3.45E-02 | 58% | 82% | 97% |
| 174 | Staten Island | 3.39E-02 | 57% | 82% | 97% |
| 179 | Twitchell Island | 3.37E-02 | 57% | 81% | 97% |
| 13 | Holland Tract | 3.37E-02 | 57% | 81% | 97% |
| 4 | Webb Tract | 3.36E-02 | 57% | 81% | 97% |
| 6 | Bradford Island | 3.36E-02 | 57% | 81% | 97% |
| 12 | McDonald Tract | 3.34E-02 | 57% | 81% | 96% |
| 143 | Rindge Tract | 3.23E-02 | 55% | 80% | 96% |
| 16 | Palm Tract | 3.11E-02 | 54% | 79% | 96% |
| 150 | Venice Island | 3.01E-02 | 53% | 78% | 95% |
| 212 | Clifton Court Forebay Water | 2.96E-02 | 52% | 77% | 95% |
| 172 | New Hope Tract | 2.93E-02 | 52% | 77% | 95% |
| 144 | Mandeville Island | 2.90E-02 | 52% | 77% | 94% |
| 147 | Grand Island | 2.86E-02 | 51% | 76% | 94% |
| 108 | Hotchkiss Tract | 2.85E-02 | 51% | 76% | 94% |
| 152 | Medford Island | 2.80E-02 | 50% | 75% | 94% |
| 175 | Canal Ranch | 2.76E-02 | 50% | 75% | 94% |
| 117 | Union Island | 2.70E-02 | 49% | 74% | 93% |
| 17 | Jones Tract-Upper and Lower | 2.65E-02 | 48% | 73% | 93% |
| 5 | Empire Tract | 2.62E-02 | 48% | 73% | 93% |
| 11 | Quimby Island | 2.47E-02 | 46% | 71% | 92% |
| 177 | Bouldin Island | 2.42E-02 | 45% | 70% | 91% |
| 169 | McCormack Williamson Tract | 2.39E-02 | 45% | 70% | 91% |
| 163 | Fabian Tract | 2.34E-02 | 44% | 69% | 90% |
| 190 | Wright-Elmwood Tract | 2.26E-02 | 43% | 68% | 90% |
| 109 | Dutch Slough East | 2.23E-02 | 43% | 67% | 89% |
| 15 | Bacon Island | 2.19E-02 | 42% | 67% | 89% |
| 87 | Terminous Tract | 2.17E-02 | 42% | 66% | 89% |
| 210 | Ryer Island | 2.02E-02 | 40% | 64% | 87% |
| 191 | Sargent Barnhart Tract | 1.99E-02 | 39% | 63% | 86% |
| 176 | Brack Tract | 1.88E-02 | 37% | 61% | 85% |
| 162 | Fabian Tract South West 2 | 1.80E-02 | 36% | 59% | 83% |
| 149 | Pierson Tract | 1.78E-02 | 36% | 59% | 83% |
| 1010 | Clifton Court Forebay South | 1.77E-02 | 36% | 59% | 83% |
| 14 | Dutch Slough West | 1.63E-02 | 33% | 56% | 80% |
| 20 | Orwood Tract | 1.57E-02 | 33% | 54% | 79% |
| 7 | King Island | 1.56E-02 | 32% | 54% | 79% |
| 1000 | Netherlands | 1.50E-02 | 31% | 53% | 78% |
| 146 | Sutter Island | 1.47E-02 | 31% | 52% | 77% |
| 170 | Glanville Tract | 1.47E-02 | 31% | 52% | 77% |
| 1013 | Bishop Tract | 1.43E-02 | 30% | 51% | 76% |
| 129 | Veale Tract 1 | 1.42E-02 | 30% | 51% | 76% |
| 32 | Coney Island | 1.39E-02 | 29% | 50% | 75% |
| 167 | Libby McNeil Tract 2 | 1.29E-02 | 28% | 48% | 73% |
| 168 | Libby McNeil Tract 1 | 1.29E-02 | 28% | 48% | 73% |
| 141 | Merritt Island | 1.27E-02 | 27% | 47% | 72% |
| 153 | Rough and Ready Island | 1.26E-02 | 27% | 47% | 72% |
| 216 | Fabian Tract South West 1 | 1.13E-02 | 25% | 43% | 68% |
| 148 | Elk Grove South West | 1.02E-02 | 23% | 40% | 64% |
| 187 | Shima Tract | 9.80E-03 | 22% | 39% | 62% |
| 183 | Rio Blanco Tract | 9.20E-03 | 21% | 37% | 60% |
| 62 | Walnut Grove | 9.05E-03 | 20% | 36% | 60% |
| 182 | Shin Kee Tract | 8.78E-03 | 20% | 36% | 58% |
| 159 | Boggs Tract | 7.80E-03 | 18% | 32% | 54% |
| 86 | Terminous Tract East | 7.63E-03 | 17% | 32% | 53% |
| 1012 | Atlas Tract | 5.70E-03 | 13% | 25% | 43% |
| 173 | Deadhorse Island | 5.55E-03 | 13% | 24% | 43% |

Table 13-3 Delta and Suisun Marsh Individual Island Rates of Seismic Failures

| URS_ID | URS Name | Annual Mean No. of Failures | Probability of Failure in 25 years | Probability of Failure in 50 years | Probability of Failure in 100 years |
|---|---|---|---|---|---|
| 115 | Upper Roberts Island | 3.30E-03 | 8% | 15% | 28% |
| 126 | Pico Naglee Tract | 3.17E-03 | 8% | 15% | 27% |
| 1016 | Smith Tract - Lincoln Village Tract | 2.24E-03 | 5% | 11% | 20% |
| 68 | Little Egbert Tract | 1.94E-02 | 38% | 62% | 86% |
| 89 | Cache Haas Tract 2 | 1.46E-02 | 31% | 52% | 77% |
| 88 | Cache Haas Tract 1 | 1.17E-02 | 25% | 44% | 69% |
| 70 | Egbert Tract | 2.77E-03 | 7% | 13% | 24% |
| 1001 | Hastings Tract | 2.59E-03 | 6% | 12% | 23% |
| 72 | Peter Pocket | 2.46E-03 | 6% | 12% | 22% |
| 203 | Simmons-Wheeler Island | 5.61E-02 | 75% | 94% | 100% |
| 204 | SM-204 | 5.61E-02 | 75% | 94% | 100% |
| 202 | SM-202 | 5.51E-02 | 75% | 94% | 100% |
| 131 | Schafter-Pintail Tract | 5.43E-02 | 74% | 93% | 100% |
| 132 | SM-132 | 5.43E-02 | 74% | 93% | 100% |
| 55 | SM-55 | 5.43E-02 | 74% | 93% | 100% |
| 56 | SM-56 | 5.43E-02 | 74% | 93% | 100% |
| 84 | SM-84 | 5.43E-02 | 74% | 93% | 100% |
| 85 | SM-85-Grizzly Island | 5.43E-02 | 74% | 93% | 100% |
| 133 | SM-133 | 3.42E-02 | 57% | 82% | 97% |
| 134 | SM-134 | 3.42E-02 | 57% | 82% | 97% |
| 54 | SM-54 | 2.80E-02 | 50% | 75% | 94% |
| 49 | SM-49 | 2.72E-02 | 49% | 74% | 93% |
| 44 | SM-44 | 2.67E-02 | 49% | 74% | 93% |
| 47 | SM-47 | 2.67E-02 | 49% | 74% | 93% |
| 40 | SM-40 | 2.67E-02 | 49% | 74% | 93% |
| 48 | SM-48 | 2.65E-02 | 48% | 73% | 93% |
| 50 | SM-50 | 2.63E-02 | 48% | 73% | 93% |
| 39 | SM-39 | 2.62E-02 | 48% | 73% | 93% |
| 41 | SM-41 | 2.58E-02 | 48% | 73% | 92% |
| 46 | SM-46 | 2.58E-02 | 48% | 73% | 92% |
| 1 | SM-1 | 2.40E-02 | 45% | 70% | 91% |
| 2 | SM-2 | 2.40E-02 | 45% | 70% | 91% |
| 58 | SM-58 | 2.40E-02 | 45% | 70% | 91% |
| 200 | Van Sickle Island | 2.36E-02 | 45% | 69% | 91% |
| 201 | Honker Bay Club | 2.36E-02 | 45% | 69% | 91% |
| 60 | SM-60 | 2.32E-02 | 44% | 69% | 90% |
| 198 | SM-198 | 2.27E-02 | 43% | 68% | 90% |
| 57 | SM-57 | 2.27E-02 | 43% | 68% | 90% |
| 43 | SM-43 | 2.13E-02 | 41% | 66% | 88% |
| 59 | SM-59 | 2.08E-02 | 41% | 65% | 88% |
| 45 | SM-45 | 1.99E-02 | 39% | 63% | 86% |
| 123 | SM-123 | 1.88E-02 | 38% | 61% | 85% |
| 124 | SM-124 | 1.85E-02 | 37% | 60% | 84% |
| 51 | SM-51 | 1.65E-02 | 34% | 56% | 81% |
| 42 | SM-42 | 1.20E-02 | 26% | 45% | 70% |
| | **TOTAL DELTA** | **1.60E+00** | **100.00%** | **100.00%** | **100.00%** |
| | **TOTAL CACHE SLOUGH AREA** | **5.36E-02** | **73.78%** | **93.13%** | **99.53%** |
| | **TOTAL SUISUN MARSH** | **1.14E+00** | **100.00%** | **100.00%** | **100.00%** |

**Table 13-4 Delta and Suisun Marsh Individual Island Rates of Seismic Failures: Seismic Source Contribution**

| URS_ID | URS Name | Fraction Contribution of Seismic Sources | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | San Andreas | Hayward | Calaveras | Concord | Mt. Diablo | Pittsburg-Kirby Hills | CRSB | Southern Midland | Hunting Creek - Berryesa | Northern Midland | Other |
| 127 | Byron Tract | 8% | 17% | 16% | 3% | 6% | 2% | 3% | 7% | 3% | 2% | 32% |
| 1006 | Upper Andrus Island | 8% | 16% | 9% | 4% | 4% | 4% | 7% | 8% | 6% | 7% | 27% |
| 1007 | Brannan-Andrus Island | 8% | 16% | 9% | 4% | 4% | 4% | 7% | 8% | 6% | 7% | 27% |
| 63 | Tyler Island | 8% | 16% | 9% | 4% | 4% | 4% | 7% | 8% | 6% | 7% | 27% |
| 1002 | Drexler Tract | 11% | 16% | 11% | 2% | 6% | 2% | 4% | 10% | 4% | 3% | 28% |
| 1003 | Roberts Island | 11% | 16% | 11% | 2% | 6% | 2% | 4% | 10% | 4% | 3% | 28% |
| 21 | Victoria Island | 8% | 17% | 15% | 3% | 6% | 2% | 3% | 7% | 3% | 3% | 32% |
| 10 | Bethel Island | 8% | 17% | 11% | 4% | 5% | 3% | 5% | 9% | 4% | 4% | 29% |
| 9 | Jersey Island | 9% | 17% | 10% | 4% | 6% | 4% | 4% | 12% | 4% | 4% | 28% |
| 1015 | Sherman Island | 8% | 17% | 9% | 5% | 5% | 4% | 6% | 9% | 5% | 5% | 28% |
| 19 | Woodward Island | 9% | 17% | 14% | 3% | 6% | 3% | 4% | 8% | 4% | 3% | 31% |
| 174 | Staten Island | 9% | 16% | 9% | 4% | 4% | 3% | 8% | 8% | 6% | 7% | 26% |
| 179 | Twitchell Island | 8% | 17% | 9% | 4% | 5% | 4% | 6% | 9% | 5% | 5% | 27% |
| 13 | Holland Tract | 9% | 17% | 11% | 4% | 6% | 3% | 4% | 10% | 4% | 4% | 29% |
| 4 | Webb Tract | 9% | 16% | 9% | 4% | 5% | 4% | 5% | 11% | 5% | 5% | 27% |
| 6 | Bradford Island | 8% | 17% | 10% | 4% | 5% | 4% | 5% | 10% | 5% | 5% | 27% |
| 12 | McDonald Tract | 9% | 16% | 12% | 3% | 6% | 3% | 5% | 8% | 4% | 4% | 29% |
| 143 | Rindge Tract | 9% | 16% | 12% | 3% | 5% | 3% | 5% | 8% | 5% | 4% | 29% |
| 16 | Palm Tract | 9% | 17% | 12% | 3% | 6% | 3% | 4% | 10% | 4% | 3% | 30% |
| 150 | Venice Island | 9% | 16% | 10% | 4% | 5% | 3% | 5% | 9% | 5% | 5% | 27% |
| 212 | Clifton Court Forebay Water | 9% | 17% | 15% | 3% | 7% | 2% | 2% | 8% | 3% | 2% | 33% |
| 172 | New Hope Tract | 9% | 16% | 8% | 4% | 4% | 3% | 8% | 8% | 7% | 8% | 25% |
| 144 | Mandeville Island | 9% | 16% | 11% | 4% | 6% | 3% | 5% | 10% | 5% | 4% | 28% |
| 147 | Grand Island | 8% | 16% | 7% | 4% | 4% | 4% | 8% | 9% | 7% | 9% | 24% |
| 108 | Hotchkiss Tract | 9% | 17% | 11% | 4% | 6% | 3% | 4% | 11% | 4% | 3% | 28% |
| 152 | Medford Island | 9% | 16% | 11% | 3% | 6% | 3% | 5% | 10% | 5% | 4% | 28% |
| 175 | Canal Ranch | 9% | 16% | 9% | 3% | 4% | 3% | 8% | 8% | 6% | 7% | 25% |
| 117 | Union Island | 10% | 16% | 16% | 3% | 7% | 2% | 2% | 7% | 3% | 2% | 33% |
| 17 | Jones Tract-Upper and Lower | 10% | 16% | 13% | 3% | 6% | 2% | 3% | 9% | 4% | 3% | 30% |
| 5 | Empire Tract | 9% | 16% | 10% | 3% | 5% | 3% | 5% | 10% | 5% | 5% | 27% |
| 11 | Quimby Island | 9% | 16% | 11% | 3% | 6% | 3% | 4% | 11% | 4% | 4% | 28% |
| 177 | Bouldin Island | 9% | 16% | 9% | 4% | 5% | 4% | 6% | 11% | 5% | 6% | 26% |
| 169 | McCormack Williamson Tract | 9% | 16% | 8% | 3% | 4% | 3% | 9% | 8% | 7% | 9% | 24% |
| 163 | Fabian Tract | 10% | 16% | 16% | 2% | 7% | 2% | 2% | 7% | 2% | 2% | 34% |
| 190 | Wright-Elmwood Tract | 10% | 16% | 12% | 3% | 6% | 3% | 4% | 9% | 4% | 4% | 29% |
| 109 | Dutch Slough East | 9% | 17% | 10% | 4% | 6% | 4% | 4% | 12% | 4% | 3% | 28% |
| 15 | Bacon Island | 9% | 16% | 11% | 3% | 6% | 3% | 4% | 12% | 4% | 3% | 29% |
| 87 | Terminous Tract | 10% | 16% | 9% | 3% | 5% | 3% | 6% | 10% | 6% | 6% | 26% |
| 210 | Ryer Island | 8% | 15% | 6% | 4% | 4% | 4% | 9% | 9% | 7% | 10% | 23% |
| 191 | Sargent Barnhart Tract | 11% | 16% | 13% | 3% | 6% | 2% | 4% | 8% | 4% | 4% | 30% |
| 176 | Brack Tract | 10% | 16% | 8% | 3% | 5% | 3% | 7% | 10% | 6% | 7% | 25% |
| 162 | Fabian Tract South West 2 | 10% | 16% | 15% | 2% | 7% | 2% | 2% | 7% | 2% | 1% | 35% |
| 149 | Pierson Tract | 8% | 15% | 6% | 4% | 4% | 4% | 10% | 8% | 8% | 12% | 22% |
| 1010 | Clifton Court Forebay South | 10% | 16% | 15% | 2% | 8% | 2% | 2% | 8% | 2% | 1% | 34% |
| 14 | Dutch Slough West | 9% | 16% | 10% | 4% | 6% | 4% | 3% | 14% | 4% | 3% | 27% |
| 20 | Orwood Tract | 10% | 16% | 11% | 3% | 7% | 3% | 3% | 13% | 3% | 2% | 29% |
| 7 | King Island | 11% | 16% | 10% | 3% | 6% | 3% | 5% | 11% | 5% | 5% | 27% |
| 1000 | Netherlands | 8% | 15% | 6% | 4% | 3% | 4% | 11% | 7% | 9% | 13% | 20% |
| 146 | Sutter Island | 8% | 15% | 6% | 4% | 4% | 4% | 10% | 9% | 8% | 12% | 22% |
| 170 | Glanville Tract | 10% | 15% | 6% | 3% | 4% | 3% | 9% | 9% | 8% | 11% | 21% |
| 1013 | Bishop Tract | 11% | 16% | 10% | 3% | 6% | 3% | 5% | 10% | 5% | 5% | 27% |
| 129 | Veale Tract 1 | 9% | 15% | 10% | 3% | 7% | 3% | 3% | 16% | 3% | 2% | 28% |
| 32 | Coney Island | 10% | 16% | 13% | 2% | 8% | 2% | 2% | 10% | 2% | 1% | 33% |
| 167 | Libby McNeil Tract 2 | 9% | 15% | 7% | 3% | 4% | 4% | 9% | 10% | 8% | 10% | 22% |
| 168 | Libby McNeil Tract 1 | 9% | 15% | 7% | 3% | 4% | 4% | 9% | 10% | 8% | 10% | 22% |
| 141 | Merritt Island | 9% | 15% | 5% | 3% | 3% | 4% | 12% | 7% | 10% | 13% | 20% |
| 153 | Rough and Ready Island | 12% | 16% | 12% | 2% | 7% | 2% | 3% | 9% | 4% | 3% | 30% |
| 216 | Fabian Tract South West 1 | 10% | 15% | 15% | 2% | 8% | 1% | 2% | 8% | 2% | 1% | 37% |
| 148 | Elk Grove South West | 10% | 15% | 5% | 3% | 3% | 3% | 10% | 8% | 9% | 13% | 19% |
| 187 | Shima Tract | 11% | 16% | 11% | 3% | 6% | 3% | 4% | 10% | 5% | 4% | 28% |
| 183 | Rio Blanco Tract | 12% | 16% | 9% | 2% | 6% | 3% | 5% | 11% | 5% | 5% | 26% |
| 62 | Walnut Grove | 10% | 15% | 6% | 3% | 4% | 3% | 8% | 11% | 8% | 10% | 21% |
| 182 | Shin Kee Tract | 12% | 16% | 9% | 2% | 5% | 3% | 5% | 12% | 6% | 5% | 25% |
| 159 | Boggs Tract | 12% | 16% | 12% | 2% | 7% | 2% | 3% | 9% | 4% | 3% | 30% |
| 86 | Terminous Tract East | 11% | 16% | 8% | 2% | 5% | 3% | 6% | 12% | 6% | 7% | 24% |
| 1012 | Atlas Tract | 12% | 16% | 10% | 2% | 6% | 2% | 4% | 11% | 5% | 4% | 27% |
| 173 | Deadhorse Island | 10% | 15% | 7% | 3% | 4% | 3% | 8% | 11% | 7% | 9% | 22% |
| 115 | Upper Roberts Island | 12% | 15% | 13% | 1% | 8% | 1% | 2% | 9% | 2% | 1% | 36% |

## Table 13-4 Delta and Suisun Marsh Individual Island Rates of Seismic Failures: Seismic Source Contribution

| URS_ID | URS Name | Fraction Contribution of Seismic Sources | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | San Andreas | Hayward | Calaveras | Concord | Mt. Diablo | Pittsburg-Kirby Hills | CRSB | Southern Midland | Hunting Creek - Berryesa | Northern Midland | Other |
| 126 | Pico Naglee Tract | 11% | 14% | 13% | 1% | 8% | 1% | 1% | 8% | 2% | 1% | 40% |
| 1016 | Smith Tract - Lincoln Village Tract | 7% | 15% | 13% | 3% | 6% | 3% | 5% | 10% | 4% | 5% | 30% |
| 68 | Little Egbert Tract | 9% | 16% | 6% | 4% | 4% | 5% | 8% | 11% | 7% | 9% | 23% |
| 89 | Cache Haas Tract 2 | 8% | 15% | 5% | 4% | 3% | 5% | 10% | 7% | 8% | 14% | 21% |
| 88 | Cache Haas Tract 1 | 8% | 14% | 5% | 4% | 3% | 5% | 11% | 7% | 8% | 16% | 20% |
| 70 | Egbert Tract | 4% | 14% | 6% | 6% | 3% | 5% | 8% | 10% | 6% | 14% | 23% |
| 1001 | Hastings Tract | 4% | 13% | 5% | 5% | 3% | 5% | 9% | 7% | 7% | 22% | 20% |
| 72 | Peter Pocket | 4% | 13% | 5% | 5% | 3% | 4% | 9% | 7% | 7% | 24% | 20% |
| 203 | Simmons-Wheeler Island | 4% | 15% | 6% | 12% | 3% | 2% | 4% | 3% | 4% | 3% | 44% |
| 204 | SM-204 | 4% | 15% | 6% | 12% | 3% | 2% | 4% | 3% | 4% | 3% | 44% |
| 202 | SM-202 | 4% | 15% | 7% | 12% | 3% | 3% | 4% | 3% | 4% | 3% | 44% |
| 131 | Schafter-Pintail Tract | 4% | 15% | 6% | 12% | 3% | 3% | 5% | 3% | 4% | 3% | 44% |
| 132 | SM-132 | 4% | 15% | 6% | 12% | 3% | 3% | 5% | 3% | 4% | 3% | 44% |
| 55 | SM-55 | 4% | 15% | 6% | 12% | 3% | 3% | 5% | 3% | 4% | 3% | 44% |
| 56 | SM-56 | 4% | 15% | 6% | 12% | 3% | 3% | 5% | 3% | 4% | 3% | 44% |
| 84 | SM-84 | 4% | 15% | 6% | 12% | 3% | 3% | 5% | 3% | 4% | 3% | 44% |
| 85 | SM-85-Grizzly Island | 4% | 15% | 6% | 12% | 3% | 3% | 5% | 3% | 4% | 3% | 44% |
| 133 | SM-133 | 4% | 14% | 5% | 13% | 2% | 4% | 5% | 3% | 5% | 4% | 41% |
| 134 | SM-134 | 4% | 14% | 5% | 13% | 2% | 4% | 5% | 3% | 5% | 4% | 41% |
| 54 | SM-54 | 4% | 15% | 5% | 17% | 2% | 2% | 4% | 2% | 3% | 2% | 45% |
| 49 | SM-49 | 4% | 15% | 4% | 18% | 2% | 2% | 4% | 2% | 4% | 2% | 44% |
| 44 | SM-44 | 4% | 15% | 4% | 18% | 2% | 2% | 5% | 2% | 4% | 2% | 43% |
| 47 | SM-47 | 4% | 15% | 4% | 17% | 2% | 2% | 4% | 2% | 4% | 2% | 44% |
| 40 | SM-40 | 4% | 15% | 4% | 18% | 2% | 2% | 5% | 2% | 4% | 2% | 43% |
| 48 | SM-48 | 4% | 15% | 5% | 16% | 2% | 2% | 4% | 2% | 4% | 2% | 44% |
| 50 | SM-50 | 4% | 15% | 5% | 16% | 2% | 2% | 4% | 2% | 4% | 2% | 44% |
| 39 | SM-39 | 4% | 15% | 4% | 18% | 2% | 2% | 5% | 2% | 4% | 2% | 43% |
| 41 | SM-41 | 4% | 16% | 5% | 14% | 2% | 2% | 5% | 2% | 5% | 3% | 42% |
| 46 | SM-46 | 4% | 15% | 4% | 17% | 2% | 2% | 5% | 2% | 4% | 2% | 43% |
| 1 | SM-1 | 4% | 14% | 5% | 15% | 2% | 3% | 5% | 2% | 4% | 3% | 43% |
| 2 | SM-2 | 4% | 14% | 5% | 15% | 2% | 3% | 5% | 2% | 4% | 3% | 43% |
| 58 | SM-58 | 4% | 14% | 5% | 15% | 2% | 3% | 5% | 2% | 4% | 3% | 43% |
| 200 | Van Sickle Island | 4% | 14% | 7% | 12% | 3% | 4% | 4% | 3% | 3% | 3% | 44% |
| 201 | Honker Bay Club | 4% | 14% | 7% | 12% | 3% | 4% | 4% | 3% | 3% | 3% | 44% |
| 60 | SM-60 | 4% | 14% | 5% | 14% | 2% | 3% | 5% | 2% | 5% | 3% | 42% |
| 198 | SM-198 | 4% | 14% | 7% | 11% | 3% | 4% | 4% | 3% | 3% | 3% | 44% |
| 57 | SM-57 | 4% | 14% | 4% | 15% | 2% | 3% | 6% | 2% | 5% | 3% | 41% |
| 43 | SM-43 | 4% | 14% | 5% | 12% | 3% | 4% | 5% | 3% | 5% | 4% | 41% |
| 59 | SM-59 | 4% | 14% | 5% | 13% | 2% | 4% | 6% | 3% | 5% | 4% | 40% |
| 45 | SM-45 | 4% | 14% | 4% | 18% | 2% | 2% | 5% | 2% | 4% | 2% | 43% |
| 123 | SM-123 | 4% | 14% | 4% | 17% | 2% | 2% | 5% | 2% | 4% | 3% | 43% |
| 124 | SM-124 | 4% | 14% | 4% | 16% | 2% | 2% | 5% | 2% | 4% | 3% | 43% |
| 51 | SM-51 | 4% | 14% | 5% | 13% | 2% | 4% | 5% | 3% | 4% | 3% | 41% |
| 42 | SM-42 | 4% | 13% | 4% | 16% | 2% | 3% | 6% | 2% | 5% | 3% | 41% |
| | **TOTAL DELTA** | **9%** | **16%** | **10%** | **3%** | **6%** | **3%** | **5%** | **9%** | **5%** | **5%** | **28%** |
| | **TOTAL CACHE SLOUGH AREA** | **6%** | **14%** | **5%** | **5%** | **3%** | **5%** | **9%** | **8%** | **7%** | **17%** | **21%** |
| | **TOTAL SUISUN MARSH** | **4%** | **14%** | **5%** | **14%** | **2%** | **3%** | **5%** | **2%** | **4%** | **3%** | **43%** |

**Table 13-5 Annual Frequencies of Exceeding *N* Simultaneous Island Failures as a Result of Flood Event**

| Number of Islands (N) | Annual Frequency of Exceedance | Probability of Exceedance in 25 Years[1] | Probability of Exceedance in 50 Years[1] | Probability of Exceedance in 100 Years[1] |
|---|---|---|---|---|
| 1 | 0.205 | 0.994 | 1.000 | 1.000 |
| 3 | 0.138 | 0.968 | 0.999 | 1.000 |
| 10 | 0.051 | 0.719 | 0.921 | 0.994 |
| 20 | 0.023 | 0.441 | 0.688 | 0.903 |
| 30 | 0.010 | 0.213 | 0.381 | 0.617 |

[1] Assumes no changes in risk in future years. The effects of the changing risks in future years are discussed in Section 14.

**Table 13-6 Delta and Suisun Marsh Individual Island Rates of Flood Failures**

| URS_ID | URS Name | Annual Mean No. of Failures | Probability of Failure in 25 years | Probability of Failure in 50 years | Probability of Failure in 100 years |
|---|---|---|---|---|---|
| 172 | New Hope Tract | 6.80E-02 | 82% | 97% | 100% |
| 166 | RD 17 (Mossdale) | 5.79E-02 | 76% | 94% | 100% |
| 1015 | Sherman Island | 5.79E-02 | 76% | 94% | 100% |
| 191 | Sargent Barnhart Tract | 5.44E-02 | 74% | 93% | 100% |
| 150 | Venice Island | 4.31E-02 | 66% | 88% | 99% |
| 63 | Tyler Island | 4.19E-02 | 65% | 88% | 98% |
| 176 | Brack Tract | 4.13E-02 | 64% | 87% | 98% |
| 182 | Shin Kee Tract | 3.89E-02 | 62% | 86% | 98% |
| 1016 | Smith Tract - Lincoln Village Tract | 3.89E-02 | 62% | 86% | 98% |
| 165 | Walthal Tract | 3.43E-02 | 58% | 82% | 97% |
| 174 | Staten Island | 3.39E-02 | 57% | 82% | 97% |
| 10 | Bethel Island | 3.23E-02 | 55% | 80% | 96% |
| 9 | Jersey Island | 3.23E-02 | 55% | 80% | 96% |
| 20 | Orwood Tract | 3.23E-02 | 55% | 80% | 96% |
| 17 | Jones Tract-Upper and Lower | 3.23E-02 | 55% | 80% | 96% |
| 118 | Pescadero | 2.93E-02 | 52% | 77% | 95% |
| 119 | Paradise Junction | 2.93E-02 | 52% | 77% | 95% |
| 157 | Smith Tract | 2.93E-02 | 52% | 77% | 95% |
| 15 | Bacon Island | 2.93E-02 | 52% | 77% | 95% |
| 12 | McDonald Tract | 2.86E-02 | 51% | 76% | 94% |
| 144 | Mandeville Island | 2.80E-02 | 50% | 75% | 94% |
| 152 | Medford Island | 2.57E-02 | 47% | 72% | 92% |
| 1000 | Netherlands | 2.57E-02 | 47% | 72% | 92% |
| 5 | Empire Tract | 2.40E-02 | 45% | 70% | 91% |
| 87 | Terminous Tract | 2.40E-02 | 45% | 70% | 91% |
| 179 | Twitchell Island | 2.23E-02 | 43% | 67% | 89% |
| 177 | Bouldin Island | 2.23E-02 | 43% | 67% | 89% |
| 153 | Rough and Ready Island | 2.18E-02 | 42% | 66% | 89% |
| 158 | Weber Tract | 1.63E-02 | 33% | 56% | 80% |
| 1006 | Upper Andrus Island | 1.56E-02 | 32% | 54% | 79% |
| 1007 | Brannan-Andrus Island | 1.56E-02 | 32% | 54% | 79% |
| 21 | Victoria Island | 1.56E-02 | 32% | 54% | 79% |
| 1008 | Stewart Tract | 1.52E-02 | 32% | 53% | 78% |
| 1009 | Mossdale R.D. No. 2107 | 1.52E-02 | 32% | 53% | 78% |
| 4 | Webb Tract | 1.47E-02 | 31% | 52% | 77% |
| 143 | Rindge Tract | 1.38E-02 | 29% | 50% | 75% |
| 187 | Shima Tract | 1.38E-02 | 29% | 50% | 75% |
| 7 | King Island | 1.38E-02 | 29% | 50% | 75% |
| 19 | Woodward Island | 1.38E-02 | 29% | 50% | 75% |
| 1002 | Drexler Tract | 1.32E-02 | 28% | 48% | 73% |
| 1003 | Roberts Island | 1.32E-02 | 28% | 48% | 73% |
| 115 | Upper Roberts Island | 1.32E-02 | 28% | 48% | 73% |
| 169 | McCormack Williamson Tract | 1.31E-02 | 28% | 48% | 73% |
| 210 | Ryer Island | 1.30E-02 | 28% | 48% | 73% |
| 6 | Bradford Island | 1.08E-02 | 24% | 42% | 66% |
| 86 | Terminous Tract East | 1.06E-02 | 23% | 41% | 65% |
| 159 | Boggs Tract | 1.04E-02 | 23% | 41% | 65% |
| 171 | Cosumnes River Area | 1.00E-02 | 22% | 39% | 63% |
| 32 | Coney Island | 9.63E-03 | 21% | 38% | 62% |
| 13 | Holland Tract | 9.07E-03 | 20% | 36% | 60% |
| 141 | Merritt Island | 8.98E-03 | 20% | 36% | 59% |
| 120 | McMullin Ranch | 8.90E-03 | 20% | 36% | 59% |
| 147 | Grand Island | 7.39E-03 | 17% | 31% | 52% |
| 14 | Dutch Slough West | 7.12E-03 | 16% | 30% | 51% |
| 77 | Elk Grove South East | 6.46E-03 | 15% | 28% | 48% |
| 175 | Canal Ranch | 6.46E-03 | 15% | 28% | 48% |
| 170 | Glanville Tract | 6.46E-03 | 15% | 28% | 48% |
| 173 | Deadhorse Island | 6.46E-03 | 15% | 28% | 48% |
| 108 | Hotchkiss Tract | 6.31E-03 | 15% | 27% | 47% |
| 183 | Rio Blanco Tract | 6.19E-03 | 14% | 27% | 46% |
| 190 | Wright-Elmwood Tract | 6.19E-03 | 14% | 27% | 46% |
| 196 | Sacramento Pocket Area | 5.90E-03 | 14% | 26% | 45% |
| 1004 | West Sacramento 2 | 5.90E-03 | 14% | 26% | 45% |
| 135 | West Sacramento 1 | 5.90E-03 | 14% | 26% | 45% |
| 1013 | Bishop Tract | 5.50E-03 | 13% | 24% | 42% |
| 11 | Quimby Island | 4.43E-03 | 10% | 20% | 36% |
| 1010 | Clifton Court Forebay South | 3.80E-03 | 9% | 17% | 32% |
| 16 | Palm Tract | 3.49E-03 | 8% | 16% | 29% |
| 1014 | McMullin Ranch-River Junction Tract | 2.90E-03 | 7% | 13% | 25% |
| 109 | Dutch Slough East | 2.90E-03 | 7% | 13% | 25% |
| 75 | N. of Glanville Tract | 2.31E-03 | 6% | 11% | 21% |
| 149 | Pierson Tract | 2.31E-03 | 6% | 11% | 21% |

Table 13-6 Delta and Suisun Marsh Individual Island Rates of Flood Failures

| URS_ID | URS Name | Annual Mean No. of Failures | Probability of Failure in 25 years | Probability of Failure in 50 years | Probability of Failure in 100 years |
|---|---|---|---|---|---|
| 148 | Elk Grove South West | 2.31E-03 | 6% | 11% | 21% |
| 167 | Libby McNeil Tract 2 | 2.25E-03 | 5% | 11% | 20% |
| 168 | Libby McNeil Tract 1 | 2.25E-03 | 5% | 11% | 20% |
| 62 | Walnut Grove | 1.84E-03 | 4% | 9% | 17% |
| 1005 | Elk Grove | 1.76E-03 | 4% | 8% | 16% |
| 197 | Elk Grove West | 1.76E-03 | 4% | 8% | 16% |
| 78 | Elk Grove South | 1.76E-03 | 4% | 8% | 16% |
| 121 | Kasson District | 1.73E-03 | 4% | 8% | 16% |
| 129 | Veale Tract 1 | 1.72E-03 | 4% | 8% | 16% |
| 126 | Pico Naglee Tract | 1.71E-03 | 4% | 8% | 16% |
| 113 | Union Island South East | 1.62E-03 | 4% | 8% | 15% |
| 127 | Byron Tract | 1.04E-03 | 3% | 5% | 10% |
| 117 | Union Island | 7.87E-04 | 2% | 4% | 8% |
| 185 | Atlas Tract East | 5.53E-04 | 1% | 3% | 5% |
| 1012 | Atlas Tract | 4.58E-04 | 1% | 2% | 4% |
| 112 | Union Island East | 7.01E-05 | 0% | 0% | 1% |
| 163 | Fabian Tract | 6.87E-05 | 0% | 0% | 1% |
| 162 | Fabian Tract South West 2 | 6.14E-05 | 0% | 0% | 1% |
| 216 | Fabian Tract South West 1 | 4.08E-05 | 0% | 0% | 0% |
| 114 | Stark Tract | 1.74E-05 | 0% | 0% | 0% |
| 146 | Sutter Island | 1.69E-05 | 0% | 0% | 0% |
| 68 | Little Egbert Tract | 2.82E-02 | 51% | 76% | 94% |
| 89 | Cache Haas Tract 2 | 2.82E-02 | 51% | 76% | 94% |
| 88 | Cache Haas Tract 1 | 2.82E-02 | 51% | 76% | 94% |
| 79 | Peter's Pocket West | 2.82E-02 | 51% | 76% | 94% |
| 72 | Peter Pocket | 2.82E-02 | 51% | 76% | 94% |
| 80 | Cache Haas Tract 1 East | 2.64E-02 | 48% | 73% | 93% |
| 69 | Egbert Tract East | 2.63E-02 | 48% | 73% | 93% |
| 82 | Hastings Tract South West | 2.63E-02 | 48% | 73% | 93% |
| 1001 | Hastings Tract | 2.63E-02 | 48% | 73% | 93% |
| 70 | Egbert Tract | 2.09E-02 | 41% | 65% | 88% |
| 41 | SM-41 | 4.75E-01 | 100% | 100% | 100% |
| 1 | SM-1 | 4.66E-01 | 100% | 100% | 100% |
| 123 | SM-123 | 4.66E-01 | 100% | 100% | 100% |
| 124 | SM-124 | 4.66E-01 | 100% | 100% | 100% |
| 2 | SM-2 | 4.66E-01 | 100% | 100% | 100% |
| 42 | SM-42 | 4.66E-01 | 100% | 100% | 100% |
| 57 | SM-57 | 4.66E-01 | 100% | 100% | 100% |
| 58 | SM-58 | 4.66E-01 | 100% | 100% | 100% |
| 60 | SM-60 | 4.66E-01 | 100% | 100% | 100% |
| 39 | SM-39 | 4.48E-01 | 100% | 100% | 100% |
| 131 | Schafter-Pintail Tract | 4.07E-01 | 100% | 100% | 100% |
| 132 | SM-132 | 4.07E-01 | 100% | 100% | 100% |
| 55 | SM-55 | 4.07E-01 | 100% | 100% | 100% |
| 56 | SM-56 | 4.07E-01 | 100% | 100% | 100% |
| 84 | SM-84 | 4.07E-01 | 100% | 100% | 100% |
| 85 | SM-85-Grizzly Island | 4.07E-01 | 100% | 100% | 100% |
| 40 | SM-40 | 3.54E-01 | 100% | 100% | 100% |
| 46 | SM-46 | 2.89E-01 | 100% | 100% | 100% |
| 202 | SM-202 | 2.60E-01 | 100% | 100% | 100% |
| 48 | SM-48 | 8.13E-02 | 87% | 98% | 100% |
| 200 | Van Sickle Island | 8.00E-02 | 86% | 98% | 100% |
| 201 | Honker Bay Club | 8.00E-02 | 86% | 98% | 100% |
| 204 | SM-204 | 8.00E-02 | 86% | 98% | 100% |
| 49 | SM-49 | 6.20E-02 | 79% | 96% | 100% |
| 44 | SM-44 | 5.51E-02 | 75% | 94% | 100% |
| 203 | Simmons-Wheeler Island | 5.00E-02 | 71% | 92% | 99% |
| 54 | SM-54 | 4.00E-02 | 63% | 86% | 98% |
| 45 | SM-45 | 3.97E-02 | 63% | 86% | 98% |
| 50 | SM-50 | 3.76E-02 | 61% | 85% | 98% |
| 47 | SM-47 | 3.34E-02 | 57% | 81% | 96% |
| 59 | SM-59 | 3.14E-02 | 54% | 79% | 96% |
| 133 | SM-133 | 1.13E-02 | 25% | 43% | 68% |
| 134 | SM-134 | 1.13E-02 | 25% | 43% | 68% |
| 51 | SM-51 | 9.26E-03 | 21% | 37% | 60% |
| 43 | SM-43 | 9.13E-03 | 20% | 37% | 60% |
| 198 | SM-198 | 5.53E-03 | 13% | 24% | 42% |
| | **TOTAL DELTA** | **1.41E+00** | **100.00%** | **100.00%** | **100.00%** |
| | **TOTAL CACHE SLOUGH AREA** | **2.67E-01** | **99.87%** | **100.00%** | **100.00%** |
| | **TOTAL SUISUN MARSH** | **8.71E+00** | **100.00%** | **100.00%** | **100.00%** |

**Table 13-7 Annual Frequencies of Exceeding *N* Simultaneous Island Failures as a Result of All Hazards**

| Number of Islands | Annual Frequency of Exceedance | Probability of Exceedance in 25 Years[1] | Probability of Exceedance in 50 Years[1] | Probability of Exceedance in 100 Years[1] |
|---|---|---|---|---|
| 1 | 0.420 | 1.000 | 1.000 | 1.000 |
| 3 | 0.220 | 0.996 | 1.000 | 1.000 |
| 10 | 0.102 | 0.922 | 0.994 | 1.000 |
| 20 | 0.055 | 0.746 | 0.936 | 0.996 |
| 30 | 0.029 | 0.515 | 0.764 | 0.945 |

[1] Assumes no changes in risk in future years. The effects of the changing risks in future years are discussed in Section 14.

### Table 13-8 Delta and Suisun Marsh Individual Island Composite Rates of Failures

| URS_ID | URS Name | Annual Mean No. of Failures | Probability of Failure in 25 years | Probability of Failure in 50 years | Probability of Failure in 100 years |
|---|---|---|---|---|---|
| 172 | New Hope Tract | 9.73E-02 | 91% | 99% | 100% |
| 1015 | Sherman Island | 9.46E-02 | 91% | 99% | 100% |
| 63 | Tyler Island | 8.39E-02 | 88% | 98% | 100% |
| 191 | Sargent Barnhart Tract | 7.43E-02 | 84% | 98% | 100% |
| 150 | Venice Island | 7.31E-02 | 84% | 97% | 100% |
| 10 | Bethel Island | 6.96E-02 | 82% | 97% | 100% |
| 9 | Jersey Island | 6.96E-02 | 82% | 97% | 100% |
| 174 | Staten Island | 6.78E-02 | 82% | 97% | 100% |
| 12 | McDonald Tract | 6.20E-02 | 79% | 95% | 100% |
| 176 | Brack Tract | 6.01E-02 | 78% | 95% | 100% |
| 17 | Jones Tract-Upper and Lower | 5.88E-02 | 77% | 95% | 100% |
| 1006 | Upper Andrus Island | 5.82E-02 | 77% | 95% | 100% |
| 1007 | Brannan-Andrus Island | 5.82E-02 | 77% | 95% | 100% |
| 166 | RD 17 (Mossdale) | 5.79E-02 | 76% | 94% | 100% |
| 21 | Victoria Island | 5.73E-02 | 76% | 94% | 100% |
| 144 | Mandeville Island | 5.69E-02 | 76% | 94% | 100% |
| 179 | Twitchell Island | 5.60E-02 | 75% | 94% | 100% |
| 1002 | Drexler Tract | 5.52E-02 | 75% | 94% | 100% |
| 1003 | Roberts Island | 5.52E-02 | 75% | 94% | 100% |
| 152 | Medford Island | 5.37E-02 | 74% | 93% | 100% |
| 15 | Bacon Island | 5.12E-02 | 72% | 92% | 99% |
| 5 | Empire Tract | 5.02E-02 | 71% | 92% | 99% |
| 4 | Webb Tract | 4.83E-02 | 70% | 91% | 99% |
| 19 | Woodward Island | 4.83E-02 | 70% | 91% | 99% |
| 20 | Orwood Tract | 4.81E-02 | 70% | 91% | 99% |
| 182 | Shin Kee Tract | 4.77E-02 | 70% | 91% | 99% |
| 177 | Bouldin Island | 4.65E-02 | 69% | 90% | 99% |
| 143 | Rindge Tract | 4.61E-02 | 68% | 90% | 99% |
| 87 | Terminous Tract | 4.57E-02 | 68% | 90% | 99% |
| 127 | Byron Tract | 4.51E-02 | 68% | 90% | 99% |
| 6 | Bradford Island | 4.45E-02 | 67% | 89% | 99% |
| 13 | Holland Tract | 4.28E-02 | 66% | 88% | 99% |
| 1016 | Smith Tract - Lincoln Village Tract | 4.11E-02 | 64% | 87% | 98% |
| 1000 | Netherlands | 4.07E-02 | 64% | 87% | 98% |
| 157 | Smith Tract | 3.91E-02 | 62% | 86% | 98% |
| 169 | McCormack Williamson Tract | 3.70E-02 | 60% | 84% | 98% |
| 147 | Grand Island | 3.59E-02 | 59% | 83% | 97% |
| 108 | Hotchkiss Tract | 3.48E-02 | 58% | 82% | 97% |
| 16 | Palm Tract | 3.46E-02 | 58% | 82% | 97% |
| 153 | Rough and Ready Island | 3.44E-02 | 58% | 82% | 97% |
| 165 | Walthal Tract | 3.43E-02 | 58% | 82% | 97% |
| 175 | Canal Ranch | 3.41E-02 | 57% | 82% | 97% |
| 210 | Ryer Island | 3.32E-02 | 56% | 81% | 96% |
| 7 | King Island | 2.94E-02 | 52% | 77% | 95% |
| 118 | Pescadero | 2.93E-02 | 52% | 77% | 95% |
| 119 | Paradise Junction | 2.93E-02 | 52% | 77% | 95% |
| 11 | Quimby Island | 2.91E-02 | 52% | 77% | 95% |
| 190 | Wright-Elmwood Tract | 2.88E-02 | 51% | 76% | 94% |
| 117 | Union Island | 2.78E-02 | 50% | 75% | 94% |
| 109 | Dutch Slough East | 2.52E-02 | 47% | 72% | 92% |
| 187 | Shima Tract | 2.36E-02 | 45% | 69% | 91% |
| 32 | Coney Island | 2.36E-02 | 45% | 69% | 91% |
| 163 | Fabian Tract | 2.35E-02 | 44% | 69% | 90% |
| 14 | Dutch Slough West | 2.34E-02 | 44% | 69% | 90% |
| 141 | Merritt Island | 2.17E-02 | 42% | 66% | 89% |
| 1010 | Clifton Court Forebay South | 2.15E-02 | 42% | 66% | 88% |
| 170 | Glanville Tract | 2.11E-02 | 41% | 65% | 88% |
| 149 | Pierson Tract | 2.01E-02 | 39% | 63% | 87% |
| 1013 | Bishop Tract | 1.98E-02 | 39% | 63% | 86% |
| 86 | Terminous Tract East | 1.83E-02 | 37% | 60% | 84% |
| 159 | Boggs Tract | 1.82E-02 | 37% | 60% | 84% |
| 162 | Fabian Tract South West 2 | 1.81E-02 | 36% | 59% | 84% |
| 115 | Upper Roberts Island | 1.65E-02 | 34% | 56% | 81% |
| 158 | Weber Tract | 1.63E-02 | 33% | 56% | 80% |
| 129 | Veale Tract 1 | 1.59E-02 | 33% | 55% | 80% |
| 183 | Rio Blanco Tract | 1.54E-02 | 32% | 54% | 79% |
| 167 | Libby McNeil Tract 2 | 1.52E-02 | 32% | 53% | 78% |
| 168 | Libby McNeil Tract 1 | 1.52E-02 | 32% | 53% | 78% |
| 1008 | Stewart Tract | 1.52E-02 | 32% | 53% | 78% |
| 1009 | Mossdale R.D. No. 2107 | 1.52E-02 | 32% | 53% | 78% |
| 146 | Sutter Island | 1.47E-02 | 31% | 52% | 77% |
| 148 | Elk Grove South West | 1.25E-02 | 27% | 47% | 71% |

Table 13-8 Delta and Suisun Marsh Individual Island Composite Rates of Failures

| URS_ID | URS Name | Annual Mean No. of Failures | Probability of Failure in 25 years | Probability of Failure in 50 years | Probability of Failure in 100 years |
|---|---|---|---|---|---|
| 173 | Deadhorse Island | 1.20E-02 | 26% | 45% | 70% |
| 216 | Fabian Tract South West 1 | 1.13E-02 | 25% | 43% | 68% |
| 62 | Walnut Grove | 1.09E-02 | 24% | 42% | 66% |
| 171 | Cosumnes River Area | 1.00E-02 | 22% | 39% | 63% |
| 120 | McMullin Ranch | 8.90E-03 | 20% | 36% | 59% |
| 77 | Elk Grove South East | 6.46E-03 | 15% | 28% | 48% |
| 1012 | Atlas Tract | 6.16E-03 | 14% | 27% | 46% |
| 196 | Sacramento Pocket Area | 5.90E-03 | 14% | 26% | 45% |
| 1004 | West Sacramento 2 | 5.90E-03 | 14% | 26% | 45% |
| 135 | West Sacramento 1 | 5.90E-03 | 14% | 26% | 45% |
| 126 | Pico Naglee Tract | 4.88E-03 | 11% | 22% | 39% |
| 1014 | McMullin Ranch-River Junction Tract | 2.90E-03 | 7% | 13% | 25% |
| 75 | N. of Glanville Tract | 2.31E-03 | 6% | 11% | 21% |
| 1005 | Elk Grove | 1.76E-03 | 4% | 8% | 16% |
| 197 | Elk Grove West | 1.76E-03 | 4% | 8% | 16% |
| 78 | Elk Grove South | 1.76E-03 | 4% | 8% | 16% |
| 121 | Kasson District | 1.73E-03 | 4% | 8% | 16% |
| 113 | Union Island South East | 1.62E-03 | 4% | 8% | 15% |
| 185 | Atlas Tract East | 5.53E-04 | 1% | 3% | 5% |
| 112 | Union Island East | 7.01E-05 | 0% | 0% | 1% |
| 114 | Stark Tract | 1.74E-05 | 0% | 0% | 0% |
| 68 | Little Egbert Tract | 4.76E-02 | 70% | 91% | 99% |
| 89 | Cache Haas Tract 2 | 4.28E-02 | 66% | 88% | 99% |
| 88 | Cache Haas Tract 1 | 3.99E-02 | 63% | 86% | 98% |
| 72 | Peter Pocket | 3.06E-02 | 54% | 78% | 95% |
| 1001 | Hastings Tract | 2.89E-02 | 51% | 76% | 94% |
| 79 | Peter's Pocket West | 2.82E-02 | 51% | 76% | 94% |
| 80 | Cache Haas Tract 1 East | 2.64E-02 | 48% | 73% | 93% |
| 69 | Egbert Tract East | 2.63E-02 | 48% | 73% | 93% |
| 82 | Hastings Tract South West | 2.63E-02 | 48% | 73% | 93% |
| 70 | Egbert Tract | 2.37E-02 | 45% | 69% | 91% |
| 41 | SM-41 | 5.01E-01 | 100% | 100% | 100% |
| 1 | SM-1 | 4.90E-01 | 100% | 100% | 100% |
| 2 | SM-2 | 4.90E-01 | 100% | 100% | 100% |
| 58 | SM-58 | 4.90E-01 | 100% | 100% | 100% |
| 60 | SM-60 | 4.89E-01 | 100% | 100% | 100% |
| 57 | SM-57 | 4.89E-01 | 100% | 100% | 100% |
| 123 | SM-123 | 4.85E-01 | 100% | 100% | 100% |
| 124 | SM-124 | 4.85E-01 | 100% | 100% | 100% |
| 42 | SM-42 | 4.78E-01 | 100% | 100% | 100% |
| 39 | SM-39 | 4.74E-01 | 100% | 100% | 100% |
| 131 | Schafter-Pintail Tract | 4.61E-01 | 100% | 100% | 100% |
| 132 | SM-132 | 4.61E-01 | 100% | 100% | 100% |
| 55 | SM-55 | 4.61E-01 | 100% | 100% | 100% |
| 56 | SM-56 | 4.61E-01 | 100% | 100% | 100% |
| 84 | SM-84 | 4.61E-01 | 100% | 100% | 100% |
| 85 | SM-85-Grizzly Island | 4.61E-01 | 100% | 100% | 100% |
| 40 | SM-40 | 3.80E-01 | 100% | 100% | 100% |
| 202 | SM-202 | 3.15E-01 | 100% | 100% | 100% |
| 46 | SM-46 | 3.15E-01 | 100% | 100% | 100% |
| 204 | SM-204 | 1.36E-01 | 97% | 100% | 100% |
| 48 | SM-48 | 1.08E-01 | 93% | 100% | 100% |
| 203 | Simmons-Wheeler Island | 1.06E-01 | 93% | 100% | 100% |
| 200 | Van Sickle Island | 1.04E-01 | 92% | 99% | 100% |
| 201 | Honker Bay Club | 1.04E-01 | 92% | 99% | 100% |
| 49 | SM-49 | 8.92E-02 | 89% | 99% | 100% |
| 44 | SM-44 | 8.18E-02 | 87% | 98% | 100% |
| 54 | SM-54 | 6.80E-02 | 82% | 97% | 100% |
| 50 | SM-50 | 6.39E-02 | 80% | 96% | 100% |
| 47 | SM-47 | 6.01E-02 | 78% | 95% | 100% |
| 45 | SM-45 | 5.96E-02 | 77% | 95% | 100% |
| 59 | SM-59 | 5.23E-02 | 73% | 93% | 99% |
| 133 | SM-133 | 4.55E-02 | 68% | 90% | 99% |
| 134 | SM-134 | 4.55E-02 | 68% | 90% | 99% |
| 43 | SM-43 | 3.04E-02 | 53% | 78% | 95% |
| 198 | SM-198 | 2.83E-02 | 51% | 76% | 94% |
| 51 | SM-51 | 2.58E-02 | 48% | 72% | 92% |
| | **TOTAL DELTA** | **2.99E+00** | **100.00%** | **100.00%** | **100.00%** |
| | **TOTAL CACHE SLOUGH AREA** | **3.21E-01** | **99.97%** | **100.00%** | **100.00%** |
| | **TOTAL SUISUN MARSH** | **9.85E+00** | **100.00%** | **100.00%** | **100.00%** |

**Table 13-9 Duration and Cost of Repair and Dewatering for Seismic Cases**

| No. of Flooded Islands | Estimated Range of Cost of Repair and Dewatering ($M) | Estimated Range of Breach Repair Time (days) | Estimated Range of Time to Dewater (days) |
|---|---|---|---|
| 1 | 43–240 | 27–106 | 136–276 |
| 3 | 204–490 | 120–330 | 270–466 |
| 10 | 620–1260 | 290–586 | 460–700 |
| 20 | 1,400–2,300 | 620–880 | 750–1,020 |
| 30 | 3,000–4,200 | 1,120–1,520 | 1,240–1,660 |

[a] The range is provided for plus and minus one standard deviation from the mean values.

**Table 13-10a Summary of Economic Costs of Flooded Islands due to Seismic Events**

| Number of Flooded Islands | In-Delta Costs ($ Million) | | | Statewide Cost ($ Million) | | | Total Cost ($ Million) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) |
| 1 | 134 | 199 | 296 | 8 | 19 | 47 | 142 | 219 | 343 |
| 3 | 436 | 647 | 961 | 63 | 154 | 376 | 499 | 801 | 1,337 |
| 5 | 775 | 1,150 | 1,706 | 200 | 489 | 1,196 | 974 | 1,638 | 2,902 |
| 10 | 1,741 | 2,584 | 3,835 | 1,061 | 2,596 | 6,354 | 2,802 | 5,180 | 10,189 |
| 15 | 2,900 | 4,304 | 6,387 | 3,026 | 7,406 | 18,127 | 5,926 | 11,710 | 24,513 |
| 20 | 4,060 | 6,024 | 8,939 | 4,991 | 12,216 | 29,899 | 9,050 | 18,240 | 38,839 |
| 30 | 7,187 | 10,665 | 15,826 | 6,032 | 14,763 | 36,135 | 13,219 | 25,428 | 51,961 |
| 50 | 11,247 | 16,689 | 24,766 | 11,022 | 26,979 | 66,034 | 22,269 | 43,668 | 90,800 |

**Table 13-10b Summary of Economic Impacts of Flooded Islands due to Seismic Events**

| Number of Flooded Islands | Value of Lost Output ($ Million) | | | Lost Employment (# of Lost Jobs) | | | Lost Labor Income ($ Million) | | | Lost Value Added ($ Million) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) |
| 1 | 27 | 52 | 100 | 162 | 281 | 488 | 7 | 12 | 20 | 11 | 20 | 39 |
| 3 | 106 | 204 | 392 | 737 | 1,276 | 2,212 | 28 | 49 | 86 | 46 | 87 | 165 |
| 5 | 201 | 385 | 740 | 1,488 | 2,578 | 4,468 | 54 | 96 | 169 | 91 | 172 | 325 |
| 10 | 475 | 912 | 1,751 | 3,863 | 6,694 | 11,600 | 135 | 238 | 420 | 226 | 429 | 811 |
| 15 | 786 | 1,510 | 2,899 | 6,750 | 11,697 | 20,271 | 229 | 405 | 715 | 387 | 732 | 1,386 |
| 20 | 1,124 | 2,158 | 4,144 | 10,030 | 17,381 | 30,119 | 335 | 591 | 1,043 | 566 | 1,071 | 2,026 |
| 30 | 1,860 | 3,572 | 6,859 | 17,526 | 30,371 | 52,630 | 570 | 1,007 | 1,777 | 966 | 1,829 | 3,461 |
| 50 | 3,510 | 6,739 | 12,940 | 35,404 | 61,352 | 106,318 | 1,115 | 1,969 | 3,476 | 1,897 | 3,590 | 6,794 |

**Table 13-11. Ecosystem Consequences Case 2 Spring Wet Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 0.1 | 0.96 | 0 | 0.3 | 0 | 3.16 | 0.21 | 0 | 1.47 | 3.51 | 2.93 | 2.23 | 7.64 | 1.44 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 0.03 | 0 | 7.59 | 0 | 0 | 0 | 6.53 | | | | | | | |

**Table 13-12. Ecosystem Consequences Case 2 Summer Average Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 0.1 | 0.96 | 0 | 0.3 | 0 | 3.16 | 0.21 | 0 | 1.47 | 3.51 | 2.93 | 2.23 | 7.64 | 1.44 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 0.03 | 0 | 7.59 | 0 | 0 | 0 | 6.53 | | | | | | | |

**Table 13-13. Ecosystem Consequences Case 2 Fall Dry Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 0.1 | 0.96 | 0 | 0.3 | 0 | 3.16 | 0.21 | 0 | 1.47 | 3.51 | 2.93 | 2.23 | 7.64 | 1.44 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 0.03 | 0 | 7.59 | 0 | 0 | 0 | 6.53 | | | | | | | |

**Table 13-14. Ecosystem Consequences Case 3 Spring Wet Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 0.1 | 0.96 | 0 | 0.3 | 0 | 3.16 | 0.21 | 0 | 1.47 | 3.51 | 2.93 | 2.23 | 7.64 | 1.44 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 0.03 | 0 | 7.59 | 0 | 0 | 0 | 6.53 | | | | | | | |

**Table 13-15. Ecosystem Consequences Case 3 Summer Average Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 0.1 | 0.96 | 0 | 0.3 | 0 | 3.16 | 0.21 | 0 | 1.47 | 3.51 | 2.93 | 2.23 | 7.64 | 1.44 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 0.03 | 0 | 7.59 | 0 | 0 | 0 | 6.53 | | | | | | | |

**Table 13-16. Ecosystem Consequences Case 3 Fall Dry Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 0.1 | 0.96 | 0 | 0.3 | 0 | 3.16 | 0.21 | 0 | 1.47 | 3.51 | 2.93 | 2.23 | 7.64 | 1.44 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 0.03 | 0 | 7.59 | 0 | 0 | 0 | 6.53 | | | | | | | |

**Table 13-17. Ecosystem Consequences Case 4 Spring Wet Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 1.21 | 1.07 | 0 | 0.98 | 0 | 16.57 | 1.4 | 0.35 | 23.39 | 3.87 | 10.42 | 2.34 | 13.72 | 7.04 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 0.4 | 0 | 9.38 | 0 | 0 | 0 | 9.37 | | | | | | | |

**Table 13-18. Ecosystem Consequences Case 4 Summer Average Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 1.21 | 1.07 | 0 | 0.98 | 0 | 16.57 | 1.4 | 0.35 | 23.39 | 3.87 | 10.42 | 2.34 | 13.72 | 7.04 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 0.4 | 0 | 9.38 | 0 | 0 | 0 | 9.37 | | | | | | | |

**Table 13-19. Ecosystem Consequences Case 4 Fall Dry Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 1.21 | 1.07 | 0 | 0.98 | 0 | 16.57 | 1.4 | 0.35 | 23.39 | 3.87 | 10.42 | 2.34 | 13.72 | 7.04 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 0.4 | 0 | 9.38 | 0 | 0 | 0 | 9.37 | | | | | | | |

**Table 13-20. Ecosystem Consequences Case 5 Spring Wet Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 7.91 | 1.75 | 0.43 | 5.11 | 0 | 23.46 | 3.79 | 0.35 | 33.02 | 8.27 | 18.06 | 2.59 | 15.25 | 12.23 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 2.88 | 0 | 16.56 | 0 | 0 | 0 | 20.3 | | | | | | | |

**Table 13-21. Ecosystem Consequences Case 5 Summer Average Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 7.91 | 1.75 | 0.43 | 5.11 | 0 | 23.46 | 3.79 | 0.35 | 33.02 | 8.27 | 18.06 | 2.59 | 15.25 | 12.23 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 2.88 | 0 | 16.56 | 0 | 0 | 0 | 20.3 | | | | | | | |

**Table 13-22. Ecosystem Consequences Case 5 Fall Dry Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 7.91 | 1.75 | 0.43 | 5.11 | 0 | 23.46 | 3.79 | 0.35 | 33.02 | 8.27 | 18.06 | 2.59 | 15.25 | 12.23 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 2.88 | 0 | 16.56 | 0 | 0 | 0 | 20.3 | | | | | | | |

**Table 13-23. Ecosystem Consequences Case 6 Spring Wet Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 11.08 | 1.95 | 0.59 | 6.25 | 0 | 29.57 | 4.94 | 0.35 | 39.49 | 8.36 | 23.55 | 7.44 | 29.19 | 16.75 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 4.03 | 0 | 32.35 | 0 | 0 | 0 | 42.52 | | | | | | | |

**Table 13-24. Ecosystem Consequences Case 6 Summer Average Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 11.08 | 1.95 | 0.59 | 6.25 | 0 | 29.57 | 4.94 | 0.35 | 39.49 | 8.36 | 23.55 | 7.44 | 29.19 | 16.75 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 4.03 | 0 | 32.35 | 0 | 0 | 0 | 42.52 | | | | | | | |

**Table 13-25. Ecosystem Consequences Case 6 Fall Dry Seismic Scenario**

| Vegetation | Vegetation types | Alkali high marsh | Alkali low marsh | Alkali middle marsh | Aquatic vegetation | Herbaceous upland, native | Herbaceous upland ruderal | Herbaceous wetland perennial | Herbaceous wetland seasonal | Herbaceous wetland ruderal | Shrub upland | Shrub wetland | Tree upland, native | Tree upland, non-native | Tree wetland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | 7748.3 | 16355.7 | 16179.7 | 4368.6 | 498.4 | 57760.5 | 16832.4 | 3171.4 | 9947.6 | 464.9 | 6410.7 | 2005.7 | 4125.6 | 6687.2 |
| | Percent | 11.08 | 1.95 | 0.59 | 6.25 | 0 | 29.57 | 4.94 | 0.35 | 39.49 | 8.36 | 23.55 | 7.44 | 29.19 | 16.75 |
| Wildlife | Wildlife species | Black Rail | Clapper Rail | Crane | Yellow throat | Harvest Mouse | Ornate Shrew | Water fowl | | | | | | | |
| | Acres | 23679.3 | 14646.5 | 174383.1 | 26300.3 | 11681.8 | 11681.8 | 418890.0 | | | | | | | |
| | Percent | 4.03 | 0 | 32.35 | 0 | 0 | 0 | 42.52 | | | | | | | |

**Table 13-26 Estimated Duration and Cost of Repair and Dewatering for Flood Cases**

| No. of Flooded Islands | Range of Cost of Repair & Dewatering ($M) | Range of Breach Repair Time (days) | Range of Time to Dewater (days) |
|---|---|---|---|
| 1 | 30–110 | 33–120 | 47–170 |
| 3 | 140–260 | 190–370 | 240–450 |
| 10 | 490–680 | 550–1,020 | 590–1,060 |
| 20 | 990–1,200 | 920–1,100 | 930–1,110 |
| 30 | 1,500–1,800 | 1,400–1,600 | 1,380–1,580 |

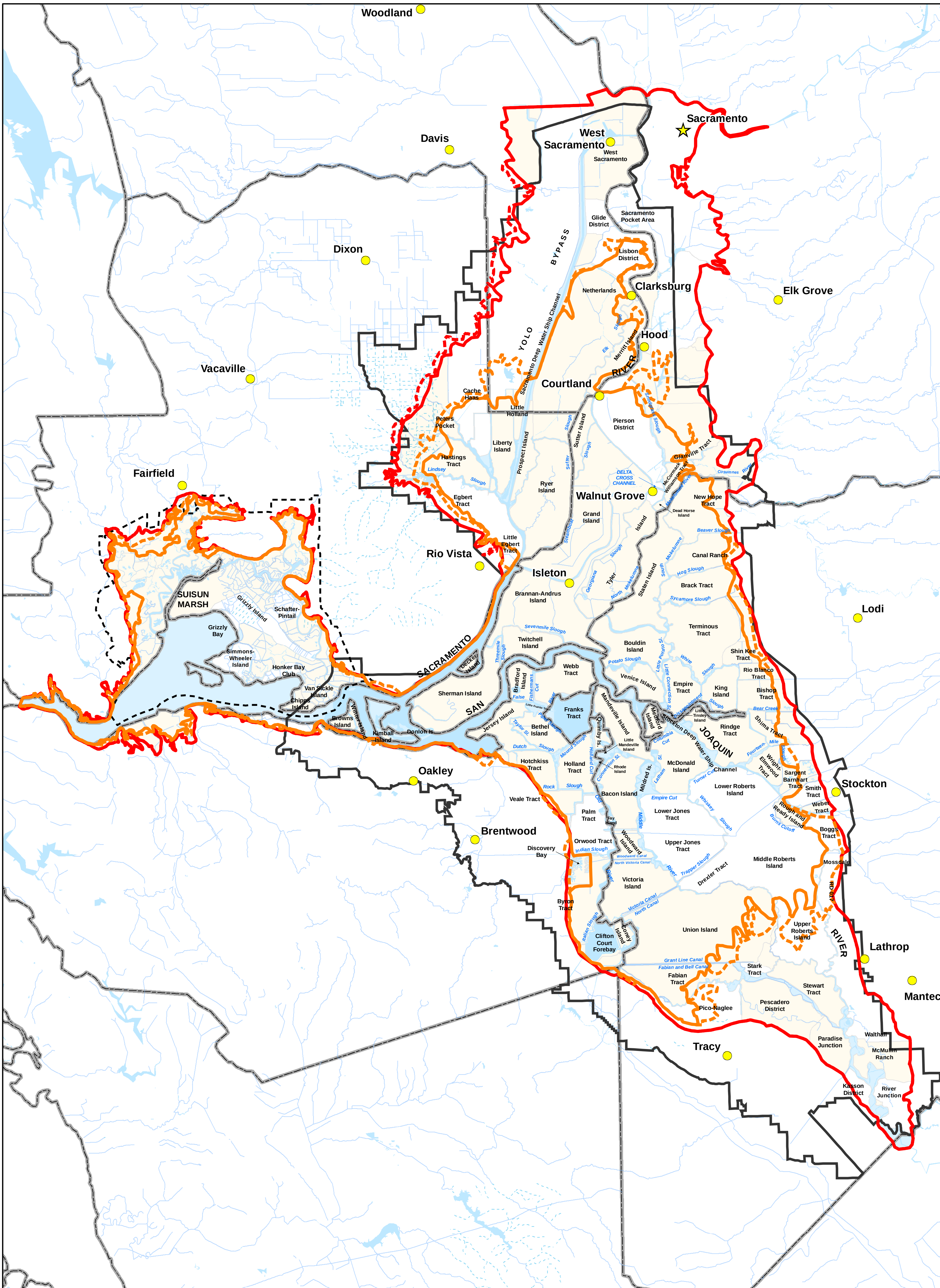
[a] The range is provided for plus and minus one standard deviation from the mean values.

**Table 13-27a Summary of Economic Costs of Flooded Islands due to Hydrological Events**

| Number of Flooded Islands | In-Delta Costs ($ Million) | | | Statewide Cost ($ Million) | | | Total Cost ($ Million) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) |
| 1 | 86 | 128 | 190 | 5 | 12 | 29 | 91 | 140 | 219 |
| 3 | 337 | 500 | 742 | 60 | 146 | 358 | 397 | 647 | 1,100 |
| 5 | 636 | 943 | 1,399 | 192 | 470 | 1,150 | 828 | 1,413 | 2,550 |
| 10 | 1,502 | 2,229 | 3,308 | 935 | 2,289 | 5,603 | 2,438 | 4,519 | 8,911 |
| 15 | 2,527 | 3,749 | 5,563 | 2,746 | 6,722 | 16,452 | 5,273 | 10,471 | 22,015 |
| 20 | 3,551 | 5,269 | 7,819 | 4,557 | 11,154 | 27,301 | 8,108 | 16,423 | 35,120 |
| 30 | 5,873 | 8,715 | 12,933 | 5,458 | 13,360 | 32,700 | 11,331 | 22,075 | 45,632 |

**Table 13-27b Summary of Economic Impacts of Flooded Islands due to Hydrological Events**

| Number of Flooded Islands | Value of Lost Output ($ Million) | | | Lost Employment (# of Lost Jobs) | | | Lost Labor Income ($ Million) | | | Lost Value Added ($ Million) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) | Lower Estimate (16% Confidence) | Median (50% Confidence) | Upper Estimate (84% Confidence) |
| 1 | 8 | 16 | 33 | 44 | 93 | 198 | 2 | 4 | 7 | 3 | 7 | 13 |
| 3 | 66 | 131 | 262 | 394 | 837 | 1,775 | 16 | 32 | 67 | 28 | 57 | 115 |
| 5 | 173 | 345 | 689 | 1,094 | 2,321 | 4,922 | 44 | 90 | 186 | 76 | 155 | 315 |
| 10 | 640 | 1,279 | 2,556 | 4,366 | 9,260 | 19,644 | 176 | 363 | 749 | 298 | 605 | 1,232 |
| 15 | 1,507 | 3,012 | 6,018 | 10,893 | 23,108 | 49,017 | 442 | 912 | 1,880 | 731 | 1,487 | 3,026 |
| 20 | 2,374 | 4,744 | 9,481 | 17,421 | 36,955 | 78,391 | 708 | 1,461 | 3,012 | 1,164 | 2,368 | 4,820 |
| 30 | 5,111 | 10,214 | 20,410 | 39,144 | 83,035 | 176,138 | 1,599 | 3,297 | 6,799 | 2,584 | 5,259 | 10,703 |




## Legend

- MHHW Boundary (Current)
- MHHW (2050)
- 100-Year Floodplain (Current)
- 100-Year Floodplain (2050)
- CA Water
- Intermittent canal, ditch, aqueduct, stream, river, or wash
- Perennial canal, ditch, or aqueduct; stream, river; Reservoir
- CA Counties
- Legal Delta
- Suisun Marsh

0 5 10 Miles

| URS | DRMS | MHHW and 100-Year Flood Boundaries | Figure 13-1 |
|---|---|---|---|
| | 26815431 | | |

URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Infrastructure\Floodplains+1 ft and subsided surface\4-1 MHHW and 100-year flood boundaries.mxd Date: 2/28/2007 12:49:32 PM Name: dhwrigh0

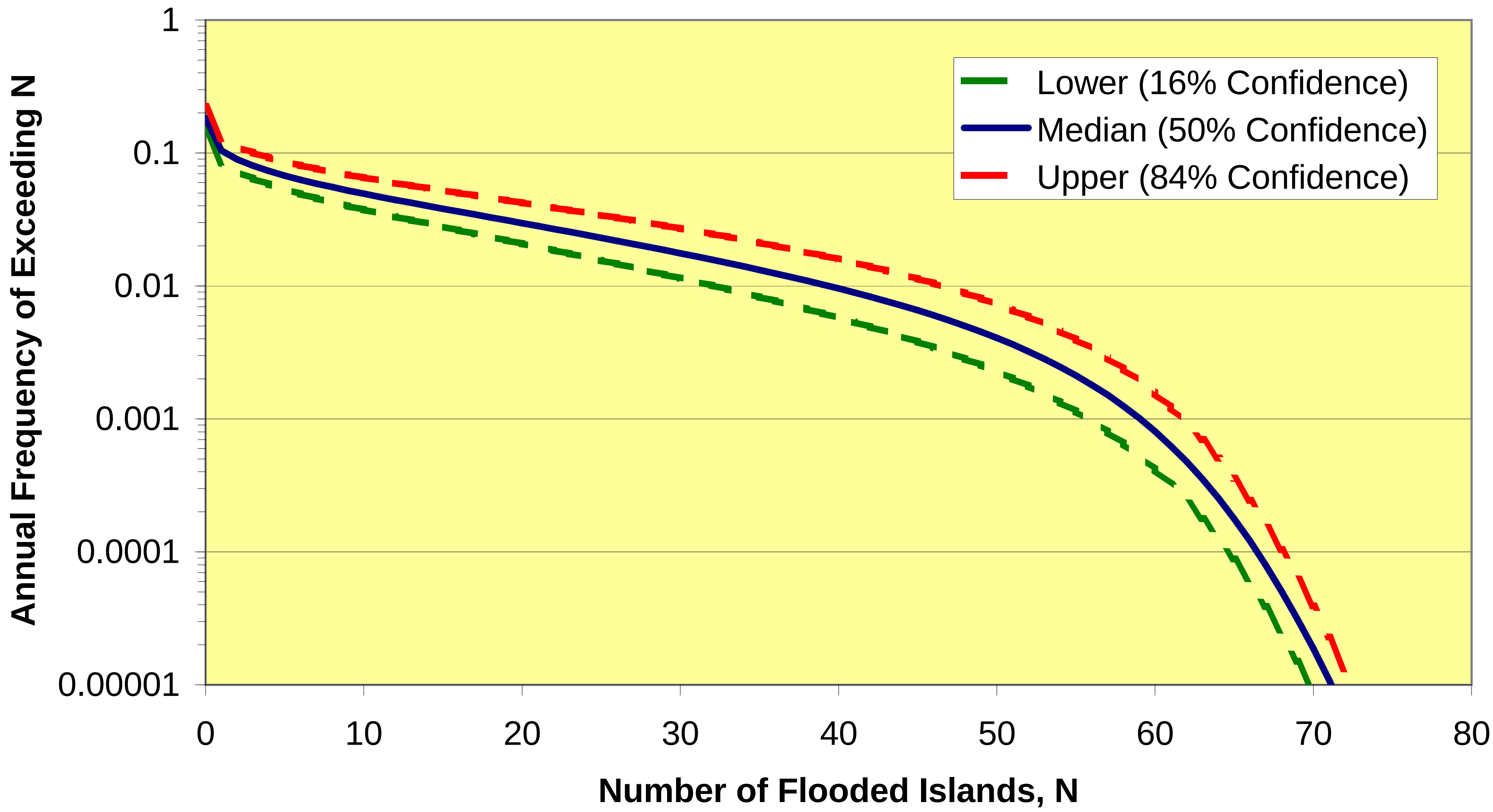



**Figure 13-2 Annual Frequency of Exceeding N Flooded Islands due to a Seismic Event**

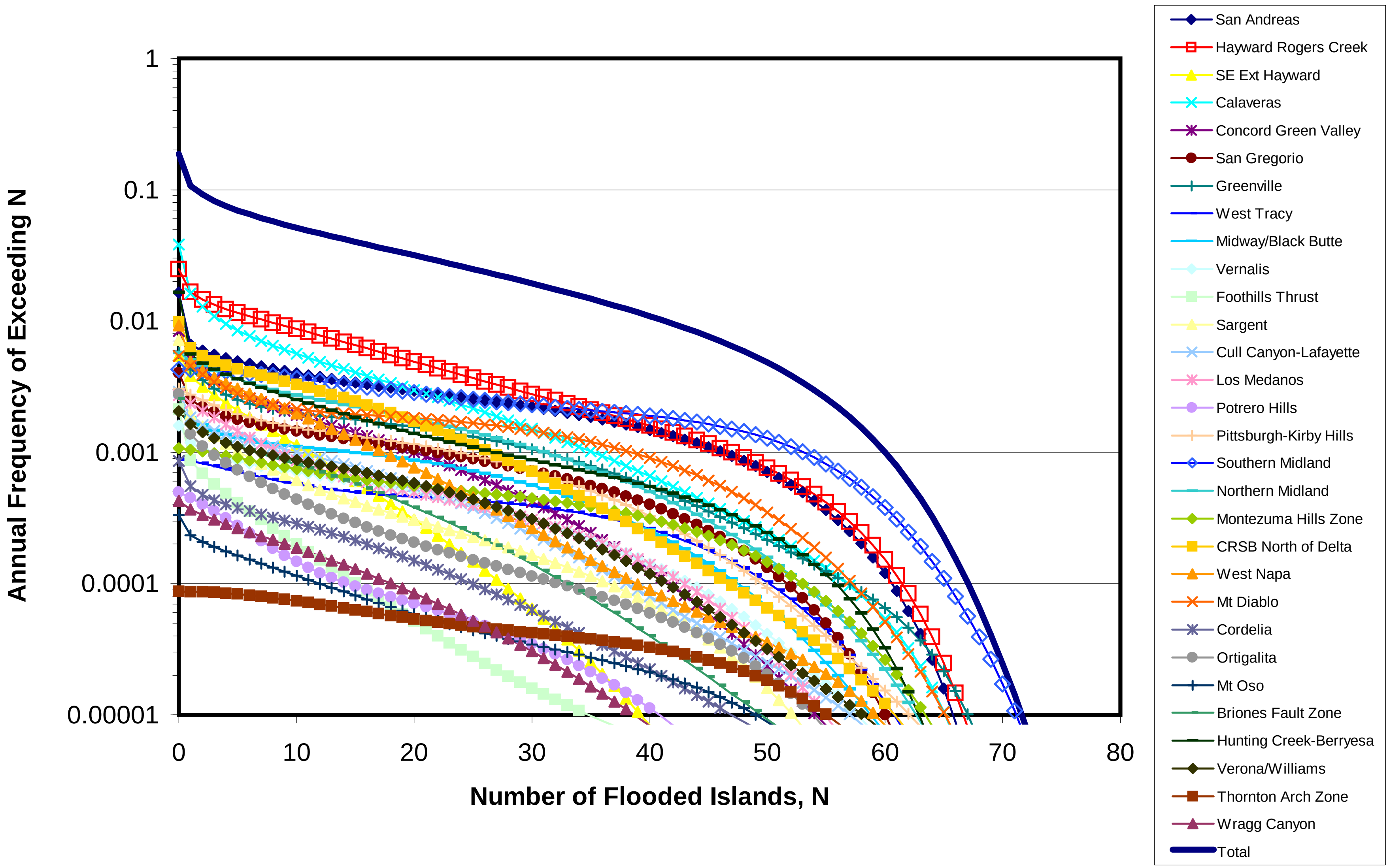



**Figure 13-3 Deaggregation of the Mean Frequency Distribution on the Number of Flooded Islands in Delta by Seismic Source**

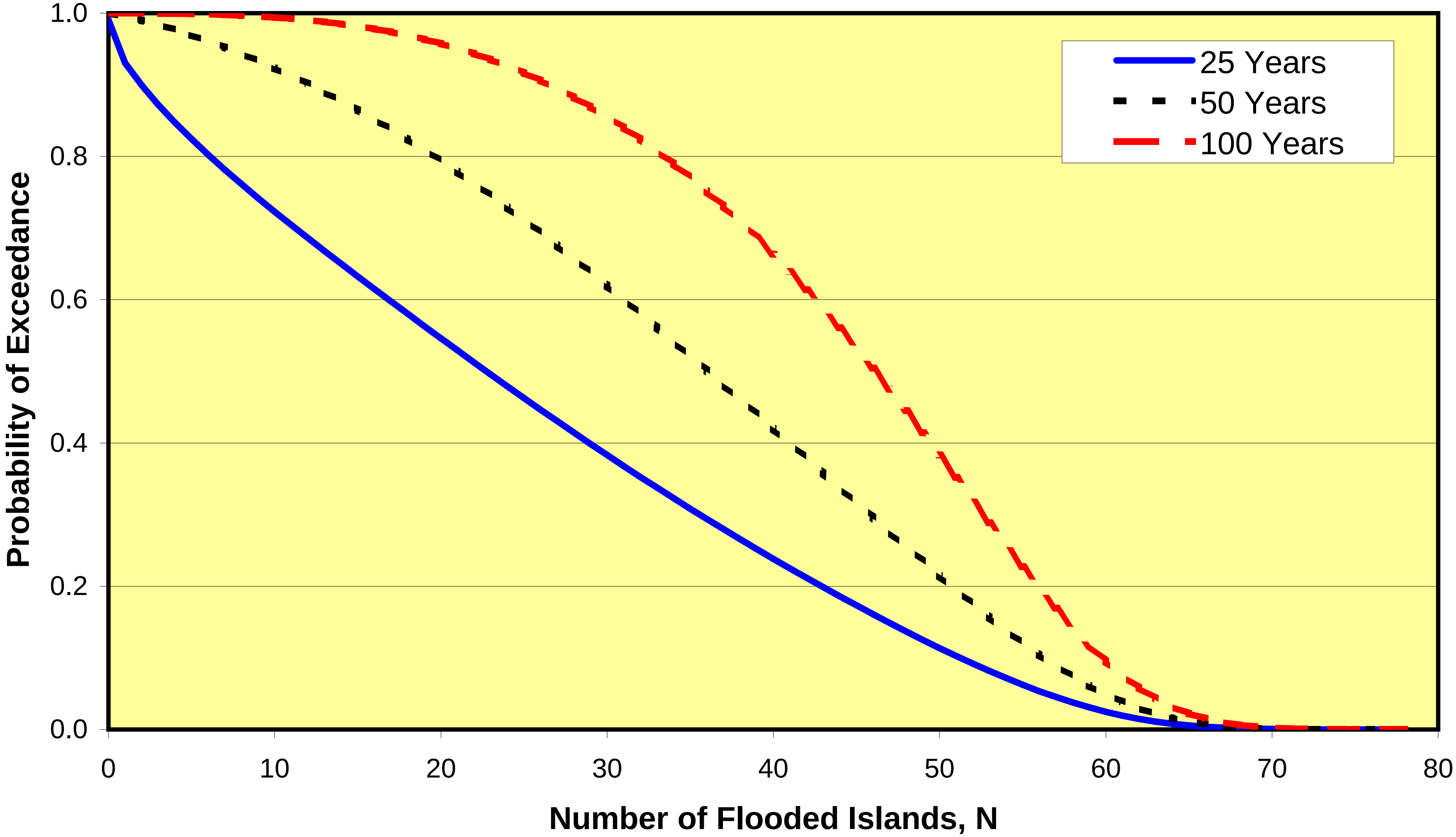



**Figure 13-4 Probability of Exceeding a Number of Simultaneous Island Failures Due to Seismic Events for Exposure Periods of 25, 50 and 100 Years**

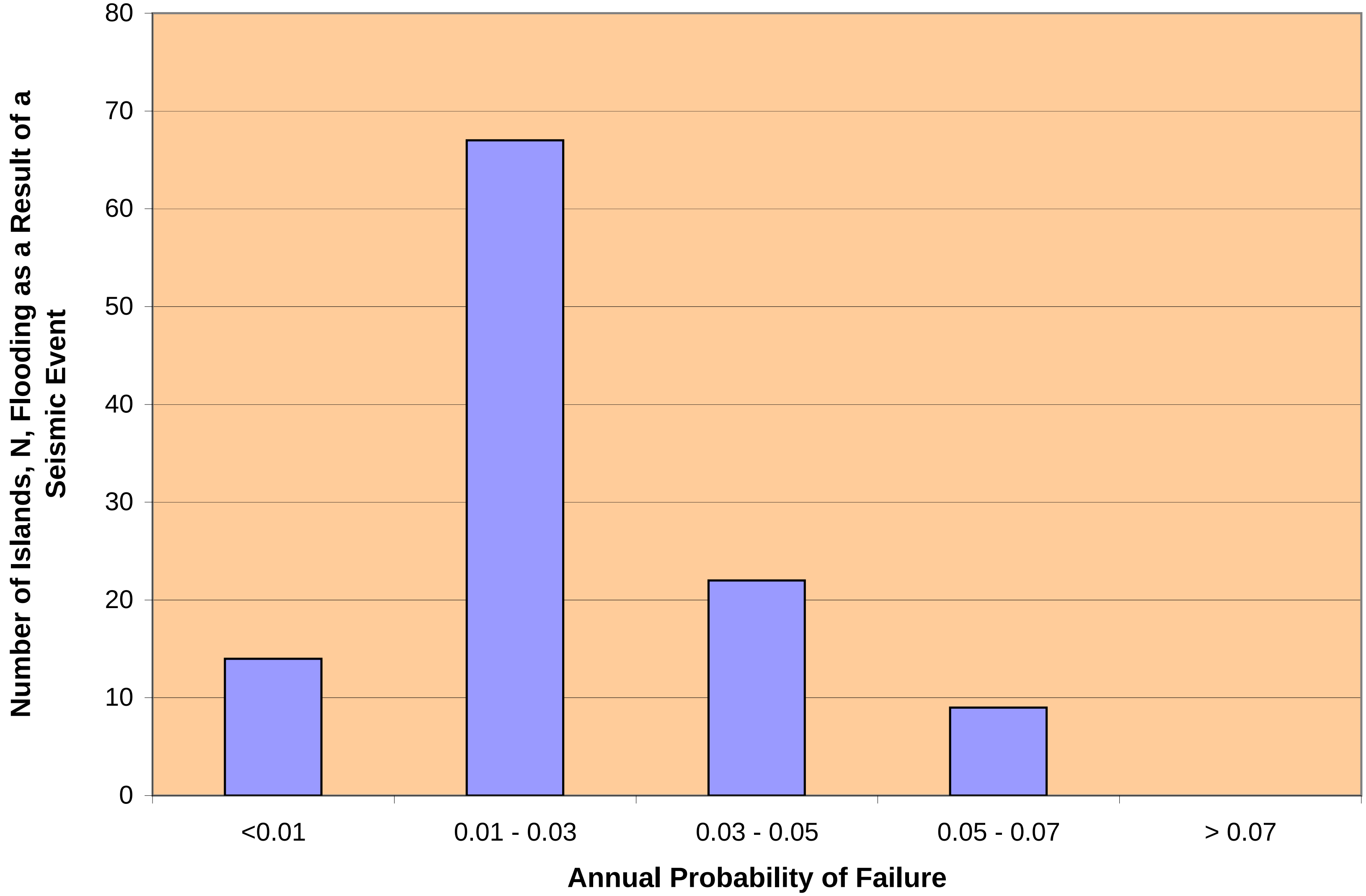



**Figure 13-5 Number of Islands in Various Seismic Failure Rate Categories**

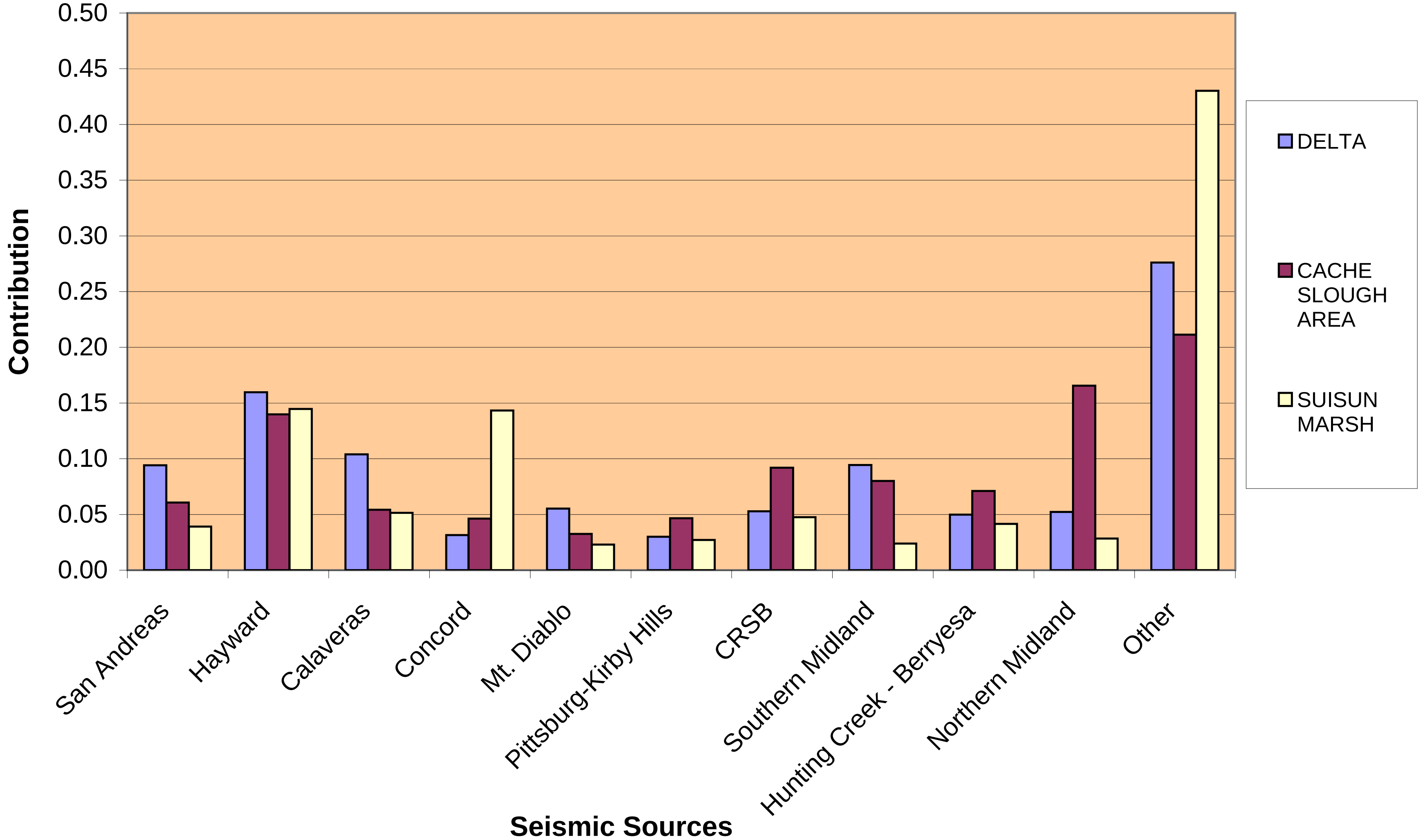
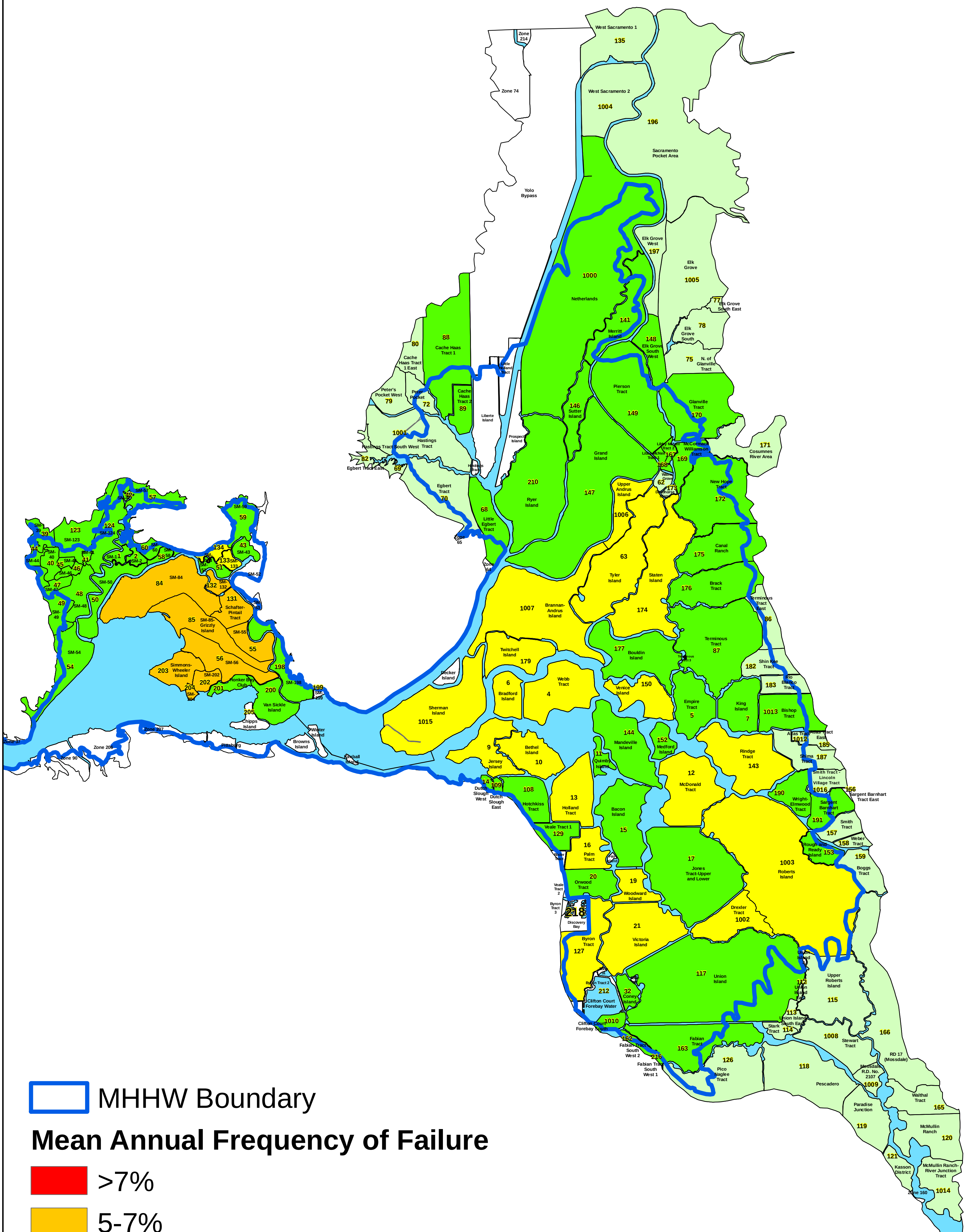



**Figure 13-6 Seismic Source Contributions to Individual Island Failures**




MHHW Boundary

**Mean Annual Frequency of Failure**

- >7%
- 5-7%
- 3-5%
- 1-3%
- <1%*

*<1% is either smaller than 1% or outside the MHHW boundary.

Notes:
Mean Higher-High Water (MHHW)
Analysis zone names and their URS IDs are shown.

0 5 10 Miles

URS

| DRMS | Mean Annual Frequency of Failure for Individual Islands Under Seismic Events | Figure 13-7 |
|---|---|---|
| 26815431 | | |

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URS Corporation, Oakland, CA, dhwright0

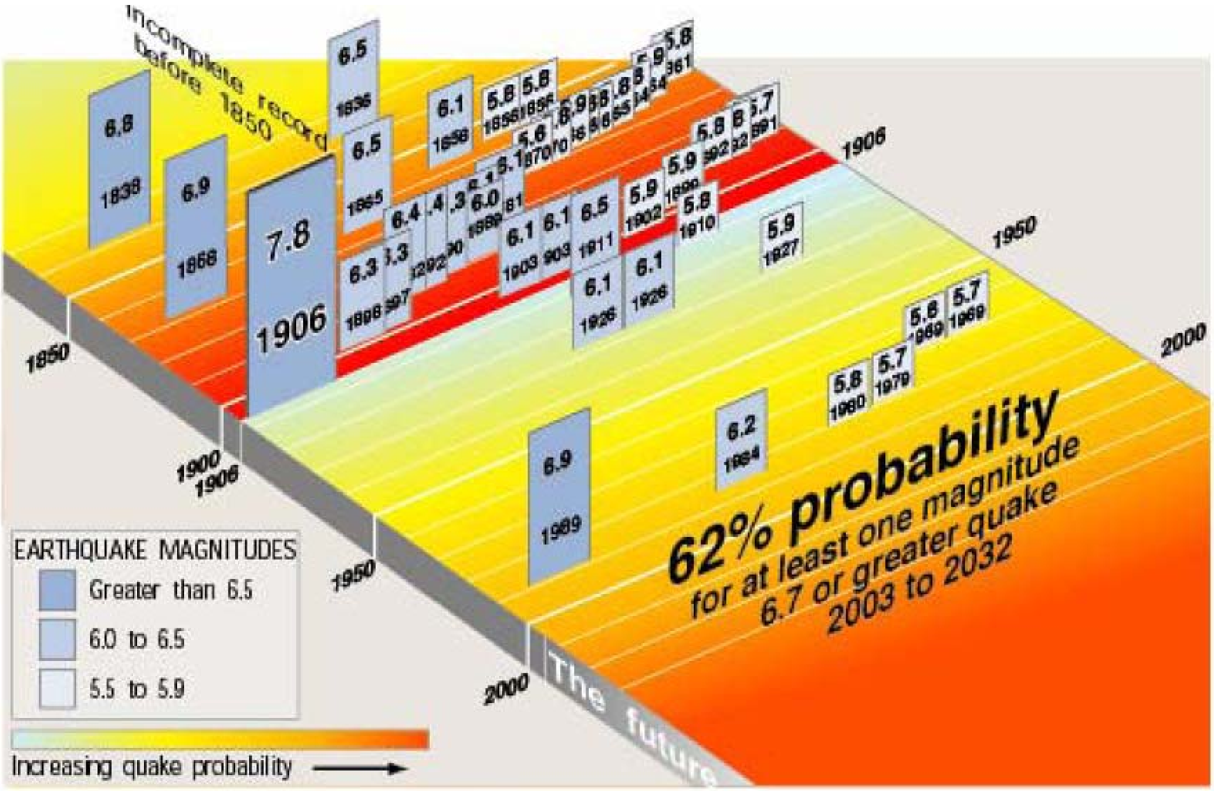



**Figure 13-8 Historical Seismicity in the Bay Area Region (WGCEP 2003)**

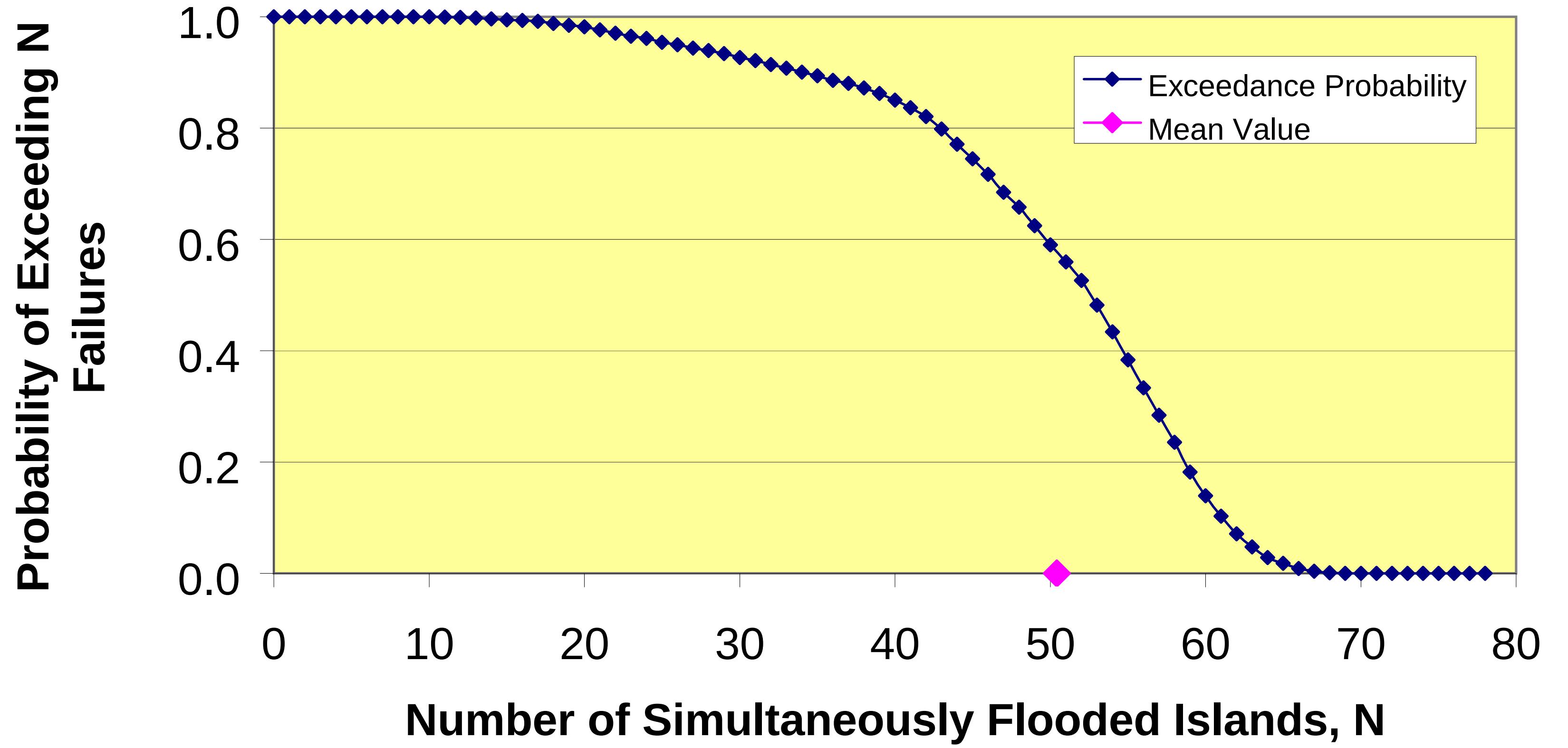



**Figure 13-9 Probability of exceeding N Flooded Islands Under a M 7.2 Hayward Earthquake Scenario**

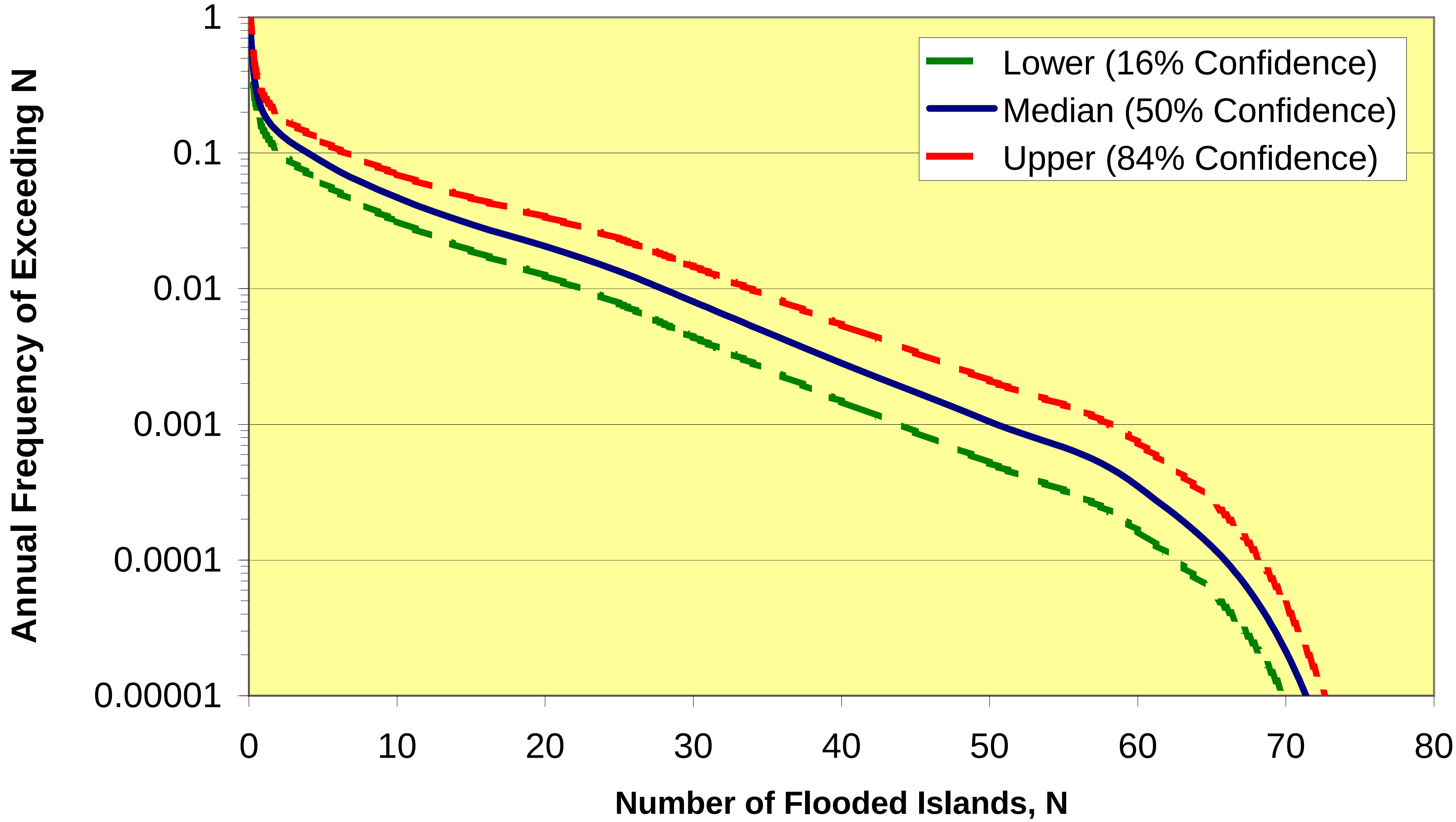



**Figure 13-10 Annual Frequency of Exceeding N Flooded Islands Due to Hydrologic Events (Flood)**

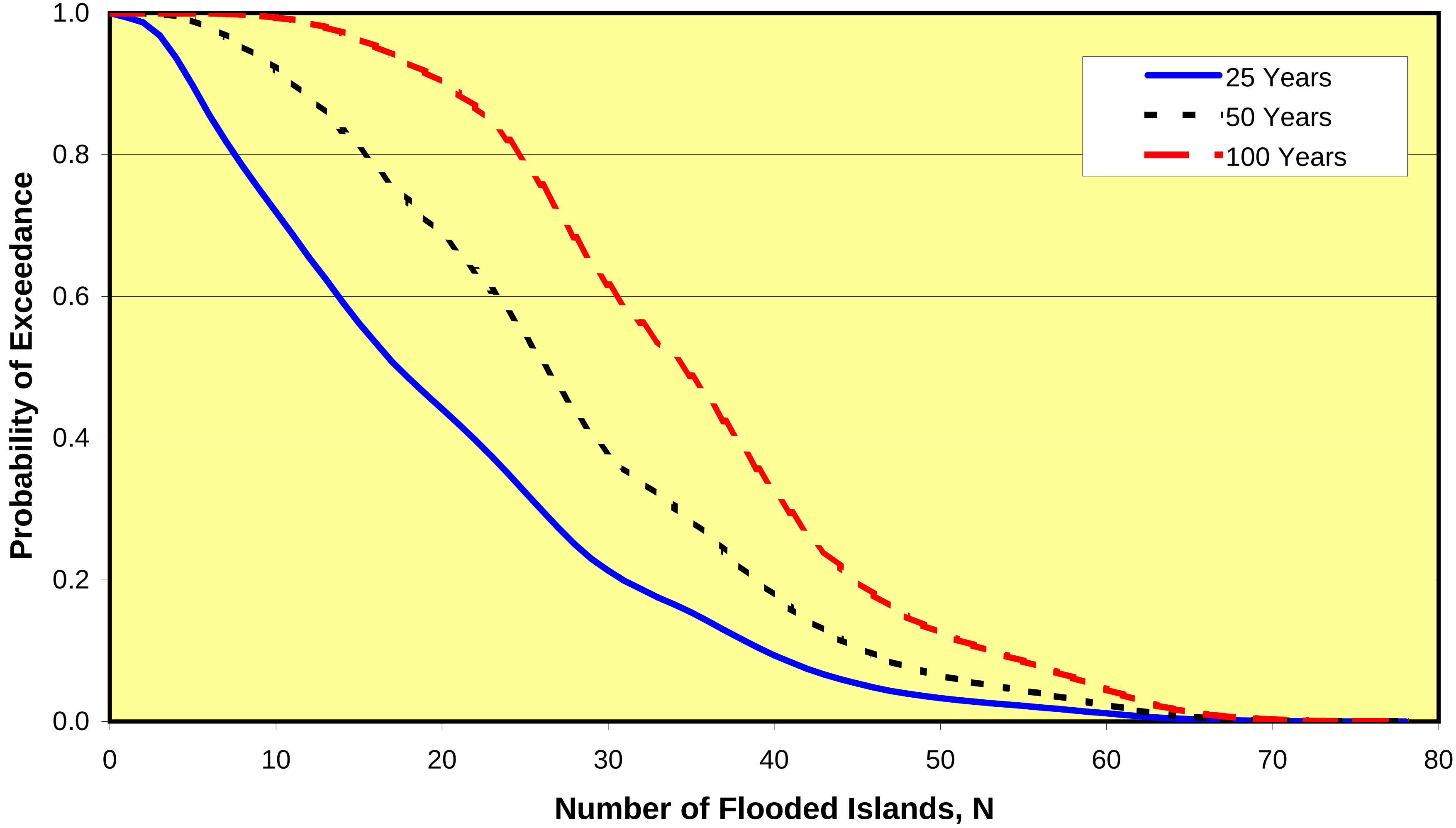



**Figure 13-11 Probability of Exceeding a Number of Simultaneous Island Failures Due to Hydrologic Events for Exposure Periods of 25, 50 and 100 Years**

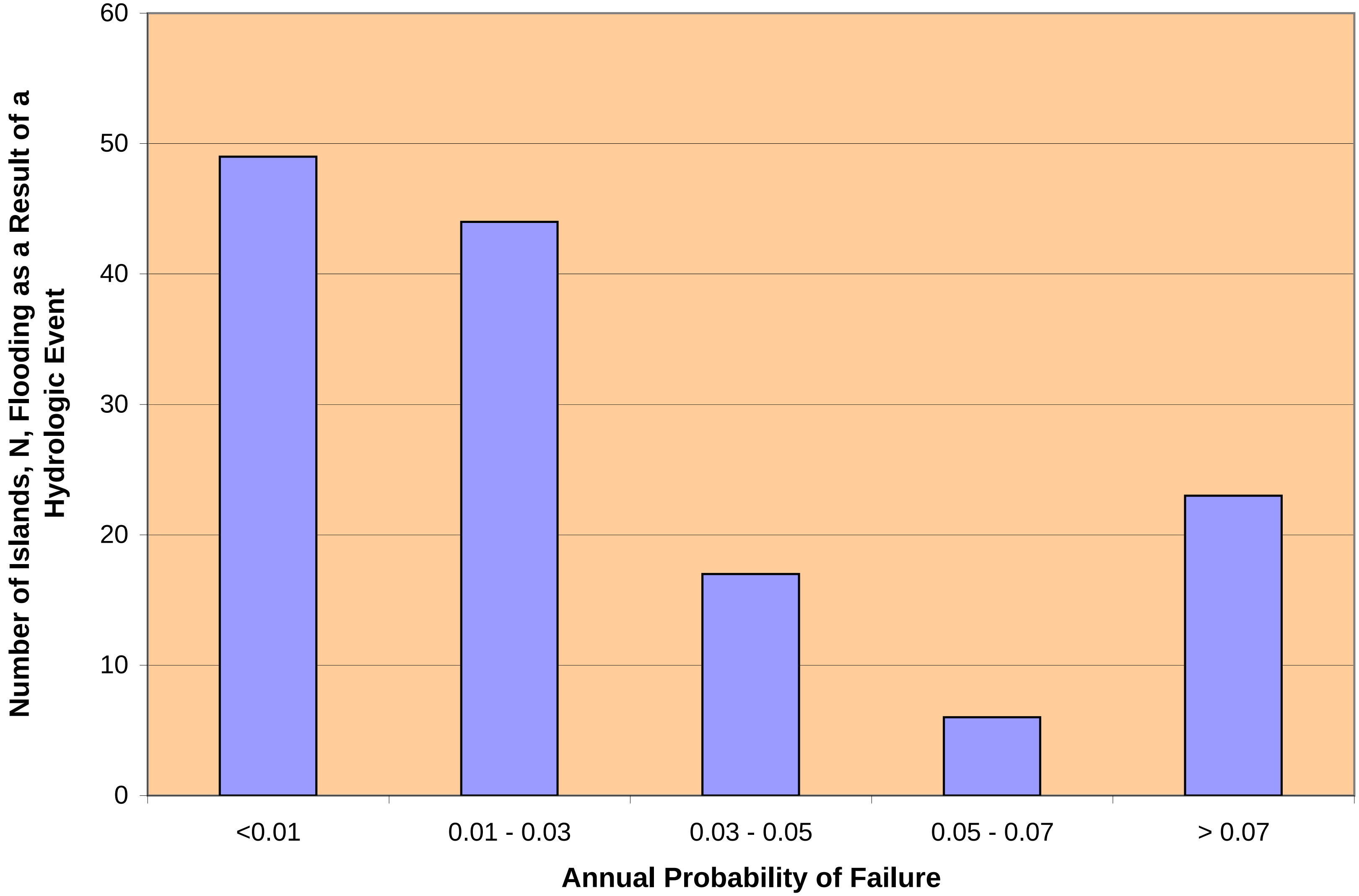
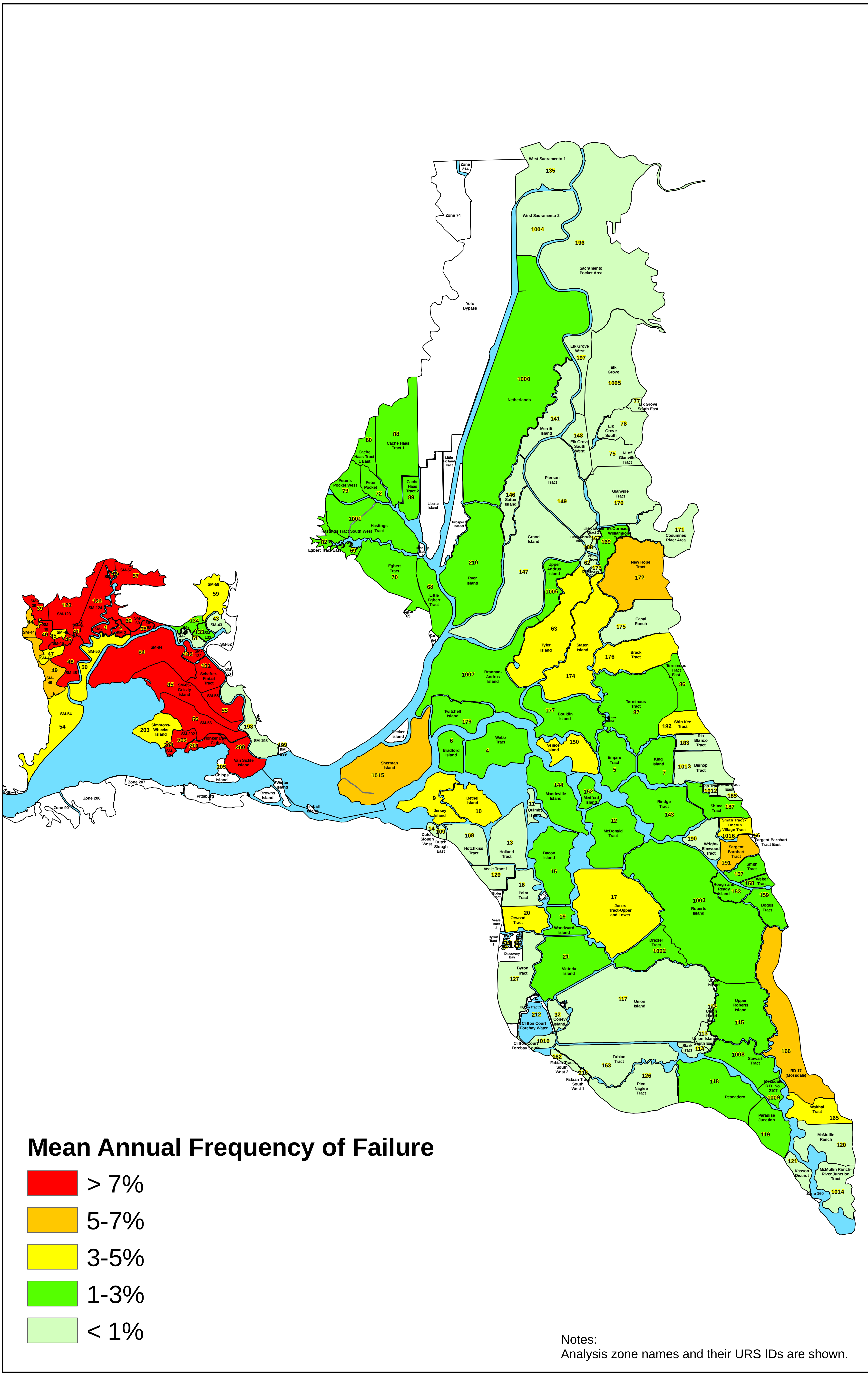



**Figure 13-12: Number of Islands in Various Flood Failure Rate Categories**

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DRMS

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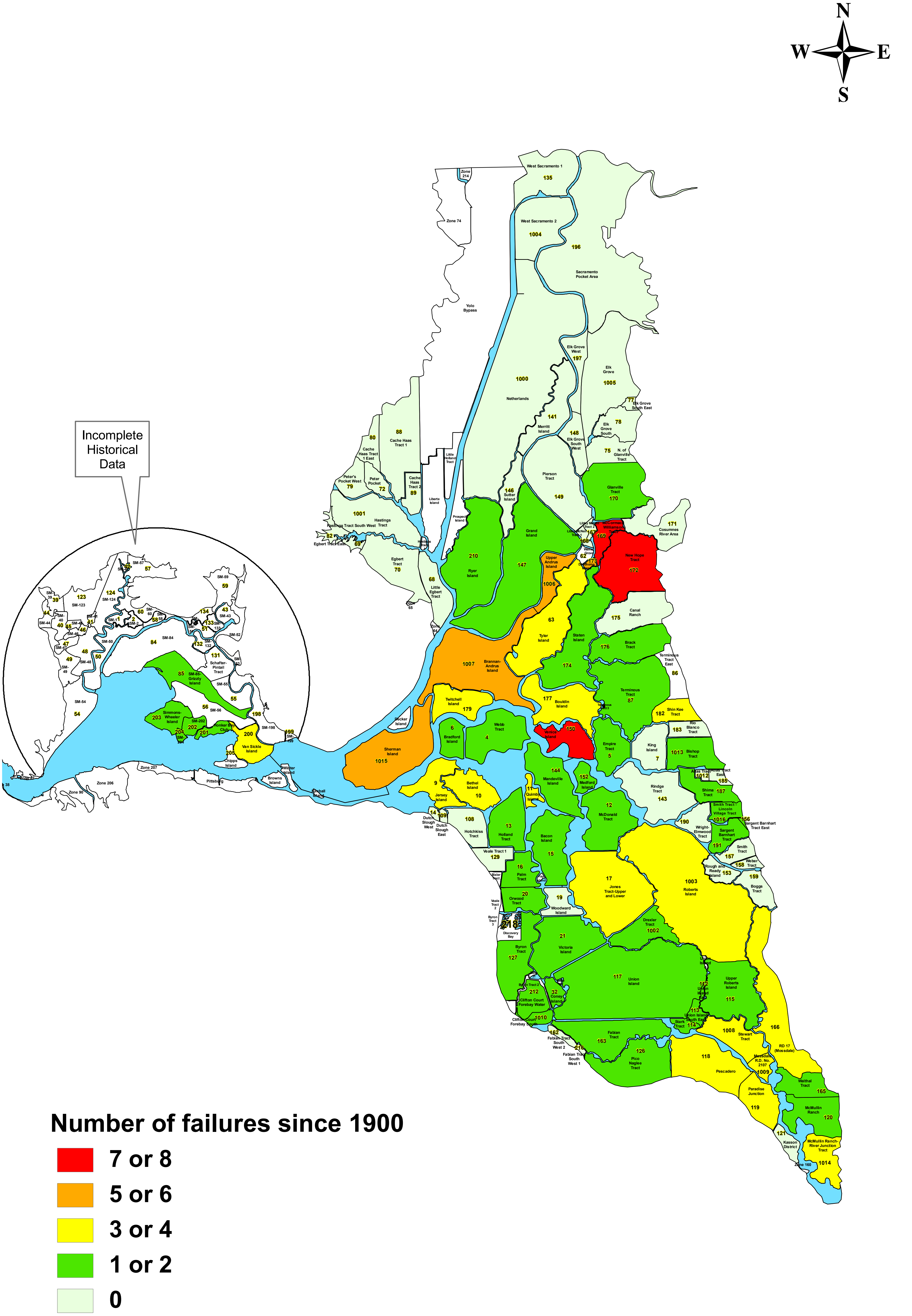
Mean Annual Frequency of Failure for Individual Islands Under Flooding Events

Figure 13-13a




Notes:
Analysis zone names and their URS IDs are shown.

0 2.5 5 10 Miles

| URS | DRMS<br>26815935 | Historical Number of Failures Since 1900 for Individual Islands Under Flooding Events | Figure 13-13b |
|---|---|---|---|

URS Corp, Oakland CA, D.Wright \\S021emc2\DRMGIS\GIS_Phase_II_Project_Files\MXD\Current Working Documents\Risk\Flooding\Fig13-13b_Historical_Inundation_Failures_16oct09.mxd - 12/11/2009 @ 3:22:44 PM

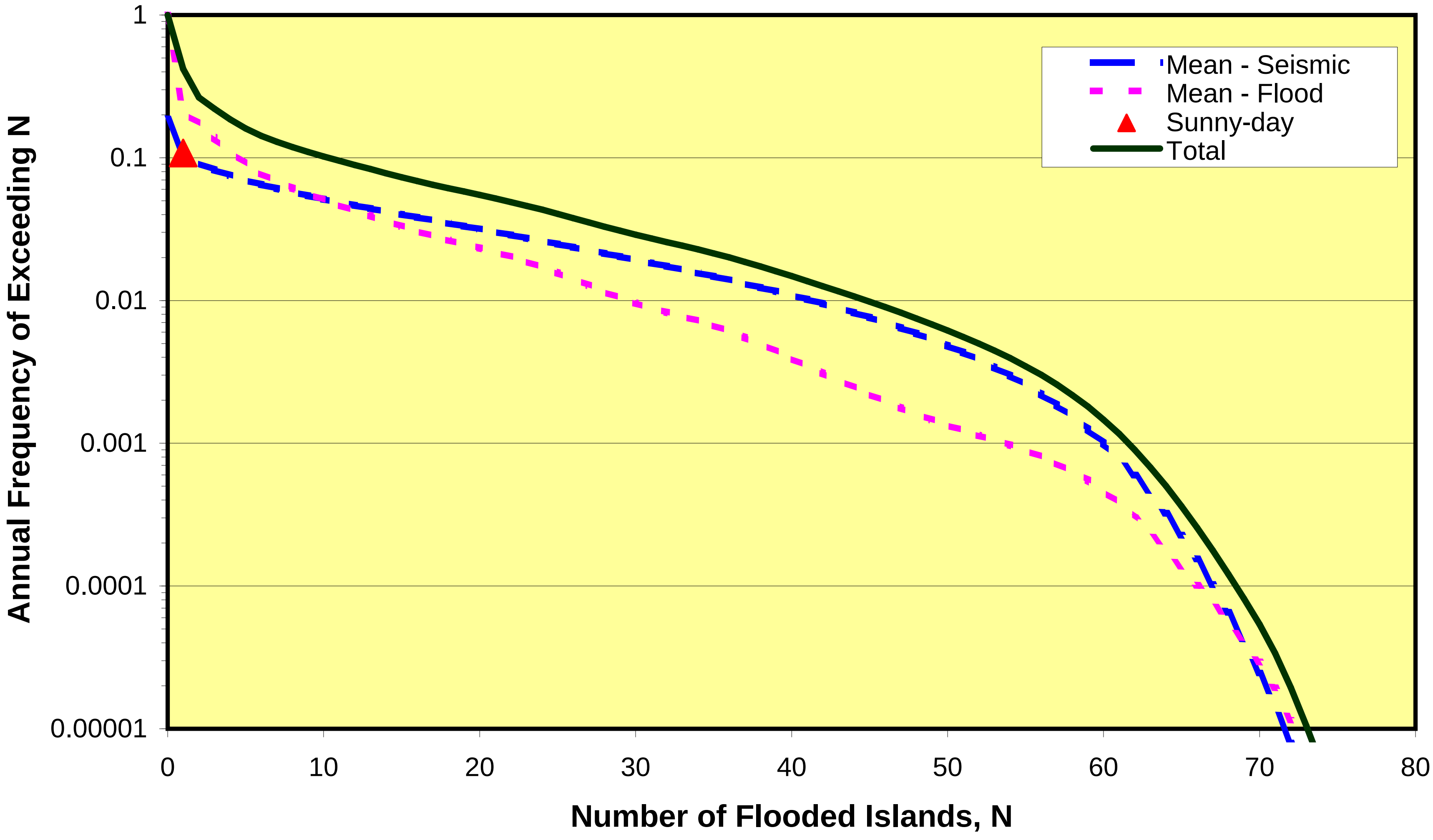



**Figure 13-14 Mean Annual Frequency of Exceeding a Number of Flooded Islands Due to Seismic, Flood and Sunny-day Events**

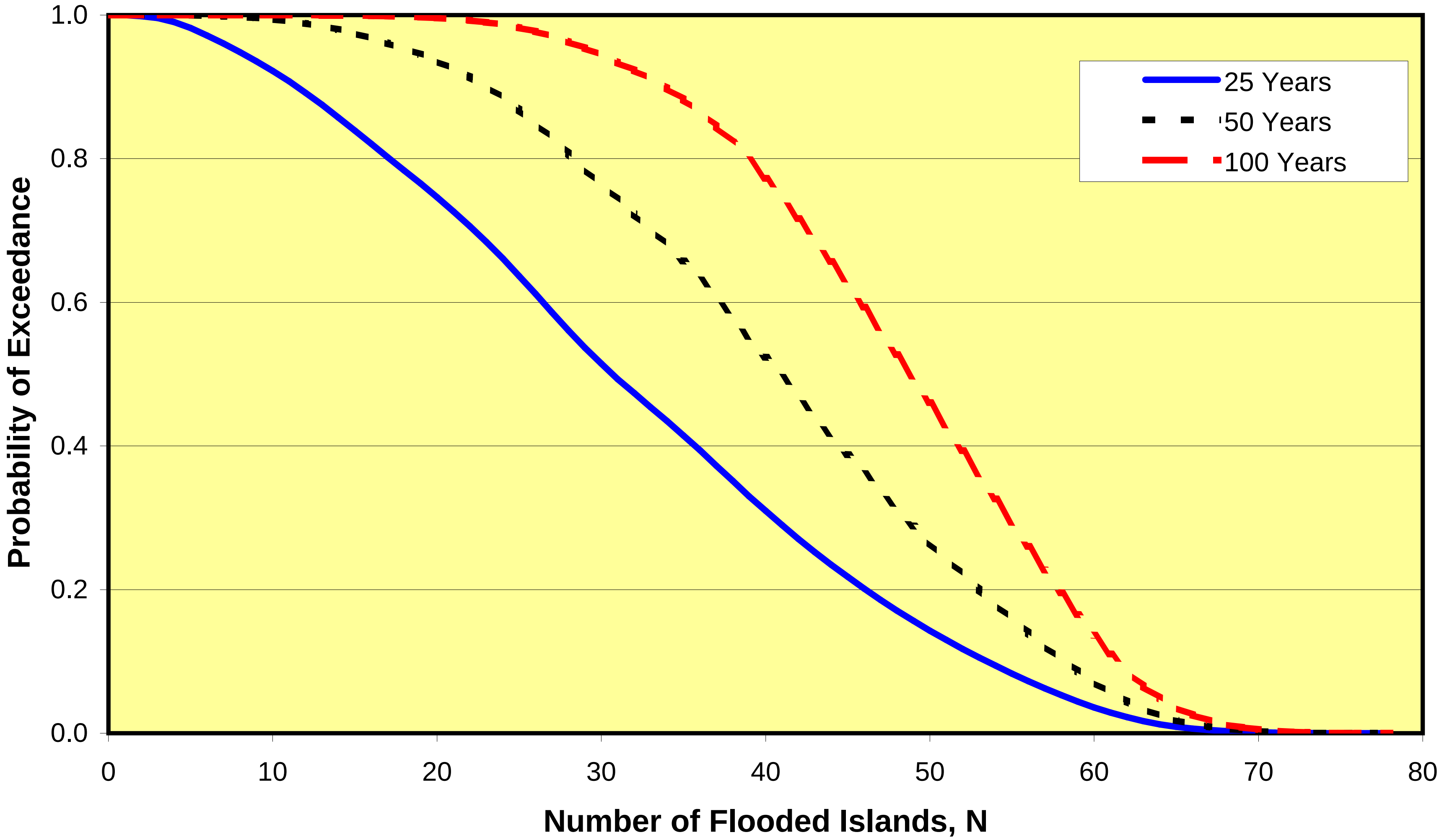
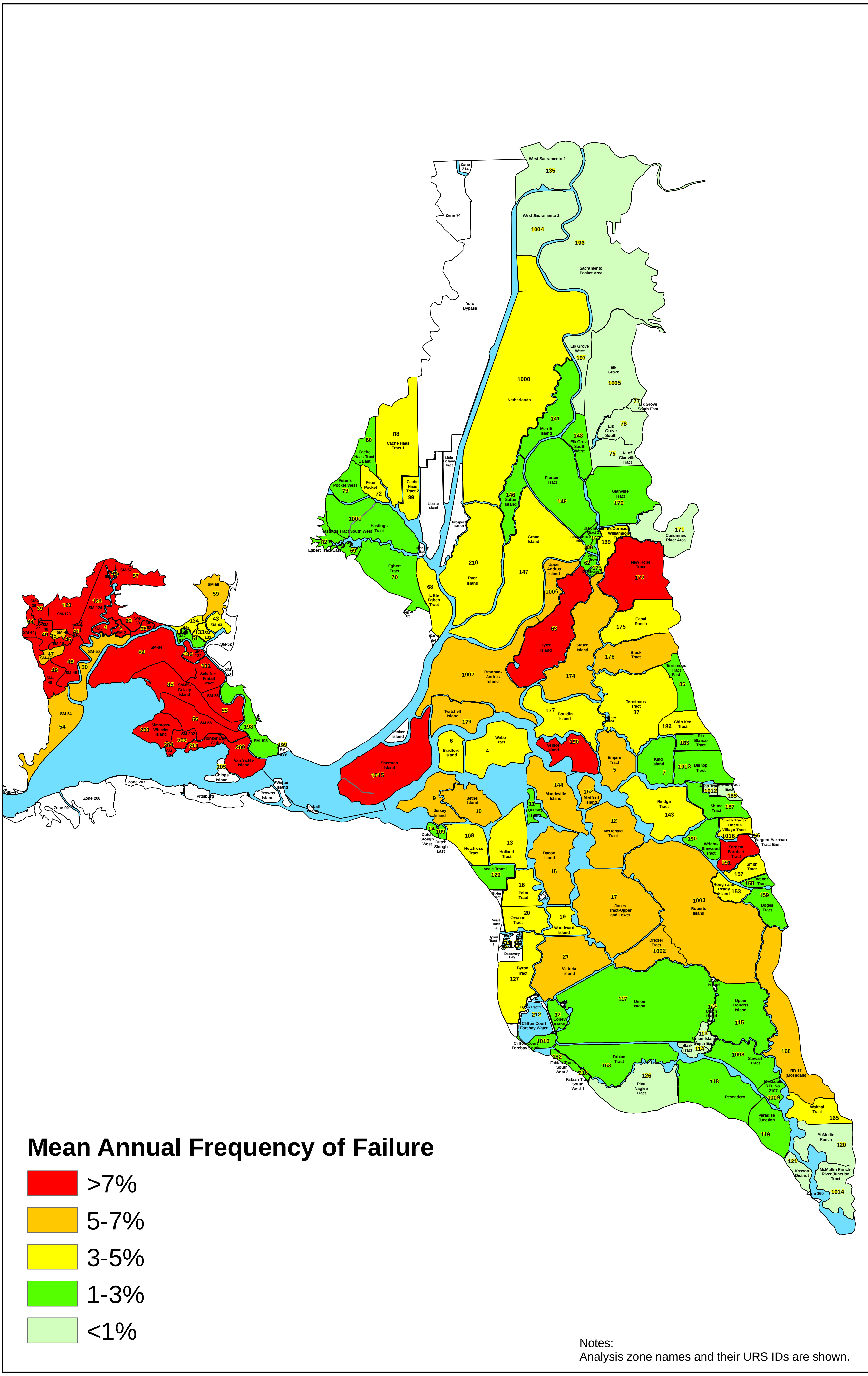



**Figure 13-15 Probability of Exceeding a Number of Simultaneous Island Failures Due to All Hazards for Exposure Periods of 25, 50 and 100 Years**

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DRMS

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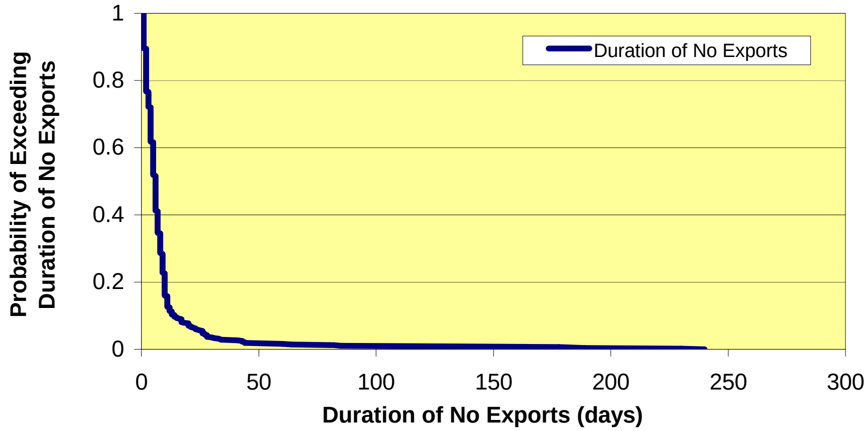
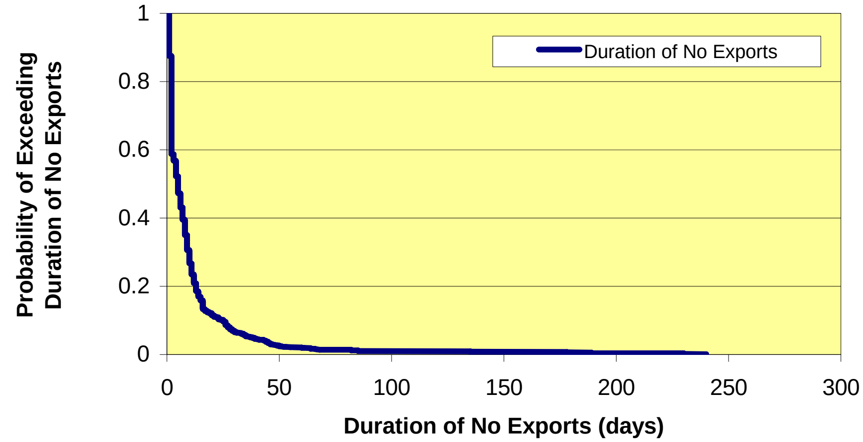
Mean Annual Frequency of Failure for Individual Islands Under Combined Flooding and Seismic Risk

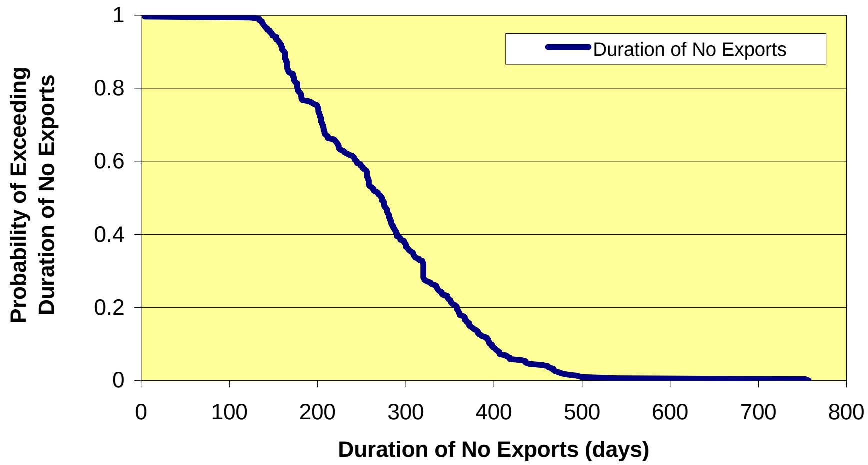
Figure 13-16



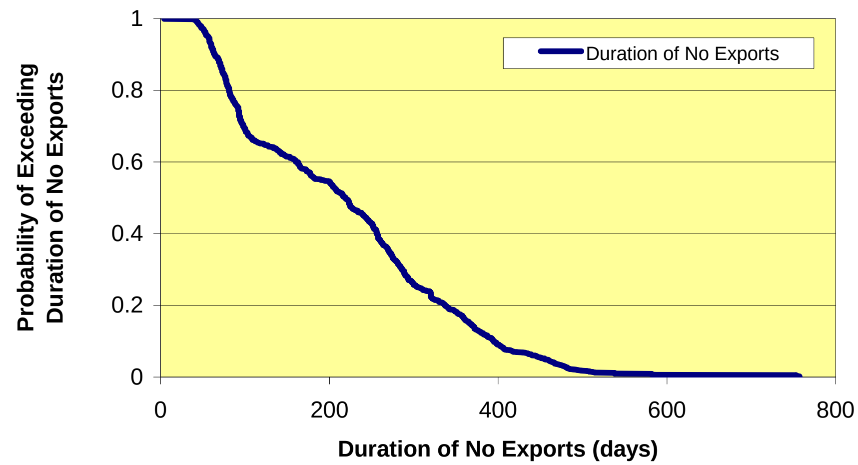

a. Three Flooded Islands; "Normal" Hydrology




b. Three Flooded Islands; "Varied" Hydrology



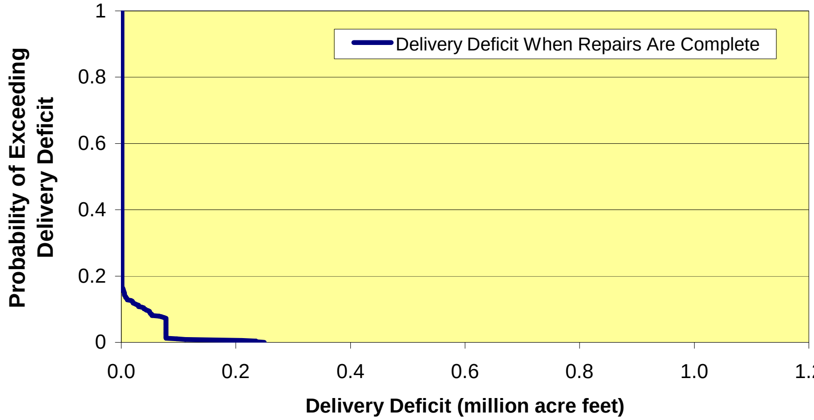

c. Twenty Flooded Islands; "Normal" Hydrology



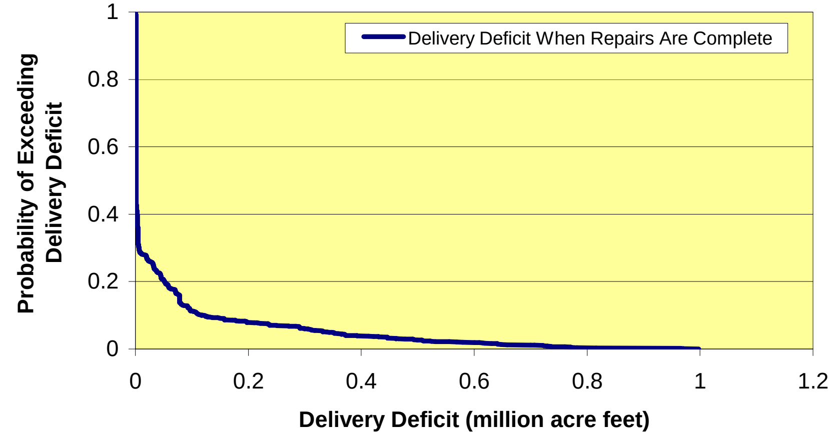

d. Twenty Flooded Islands; "Varied" Hydrology

**Figure 13-17 Durations of No Exports for Simulated Three-Island and Twenty-Island Sequences**

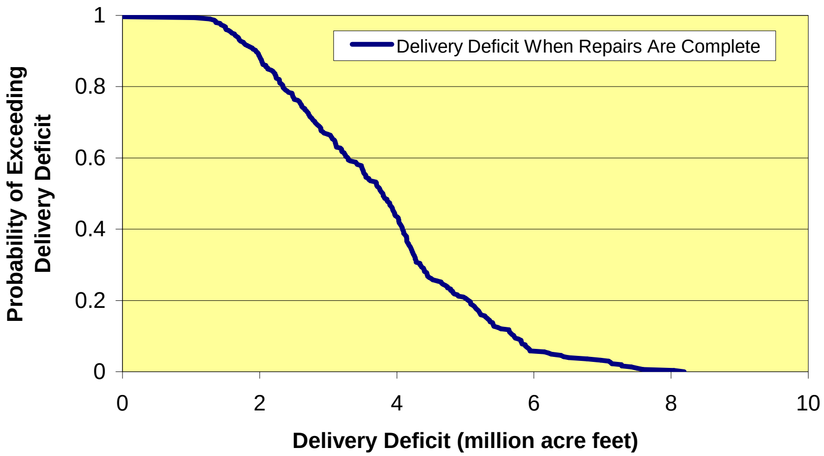
(see text for definitions of "Normal" and "Varied" hydrology)



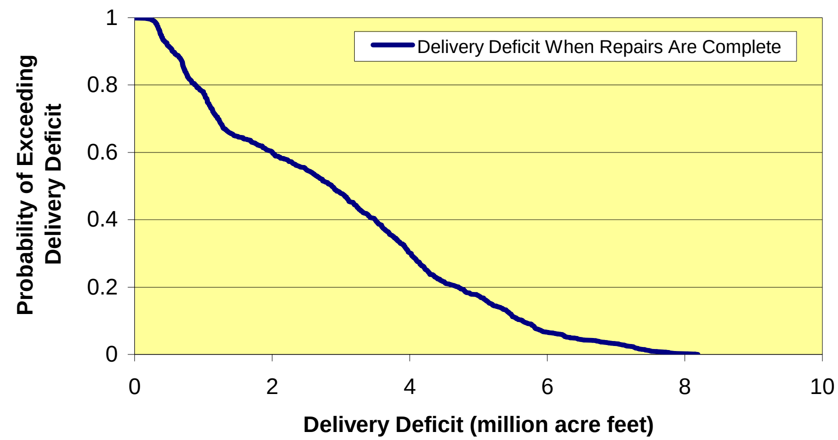

a. Three Flooded Islands; "Normal" Hydrology




b. Three Flooded Island; "Varied" Hydrology




c. Twenty Flooded Islands; "Normal" Hydrology




d. Twenty Flooded Islands; "Varied" Hydrology

**Figure 13-18 South of Delta Delivery Deficits at Completion of Repairs for Simulated Three-Island and Twenty-Island Sequences**

(see text for definitions of "Normal" and "Varied" hydrology)

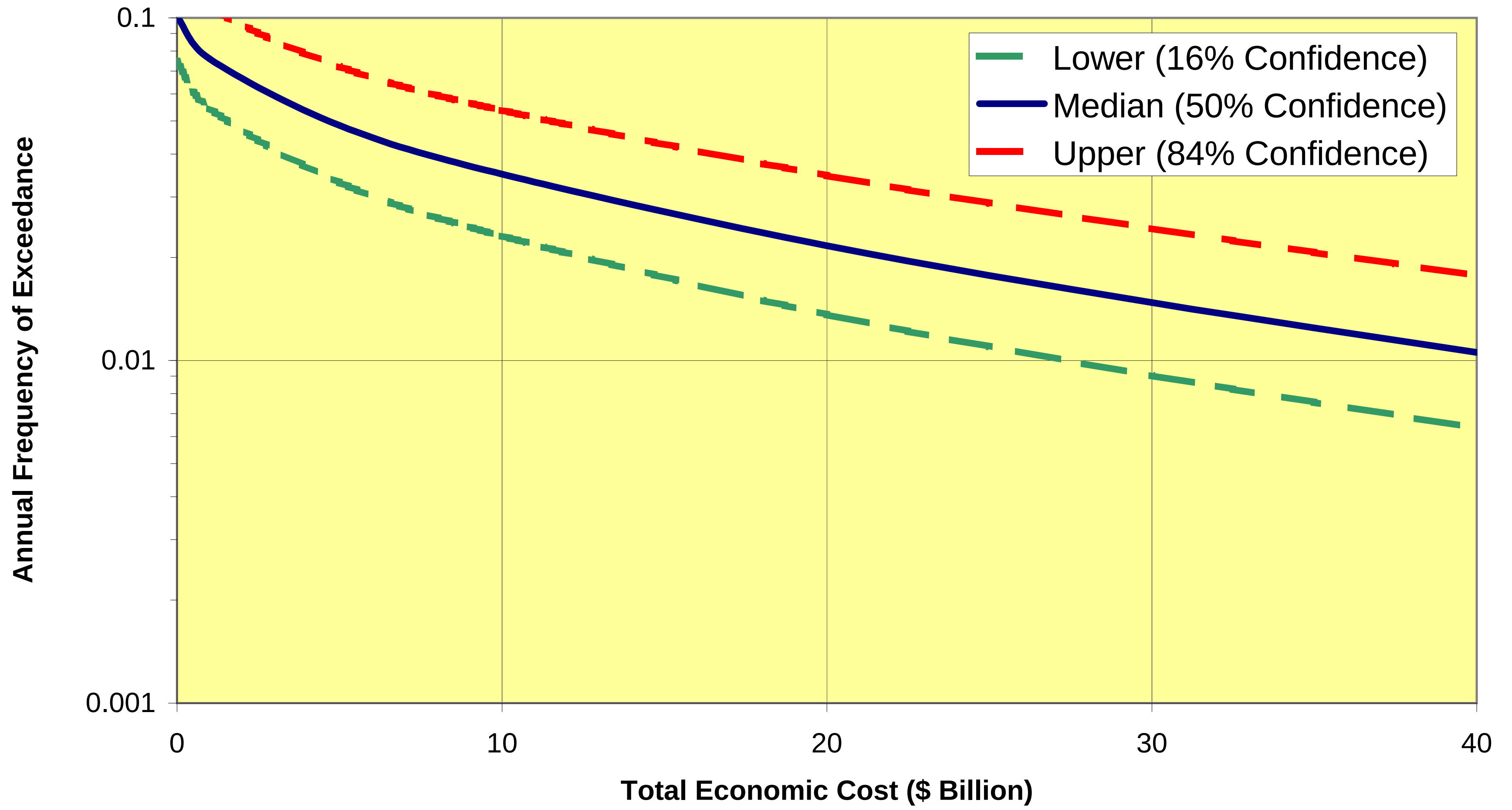



**Figure 13-19a Annual Frequency of Exceeding Total Economic Cost due to Seismic Events**

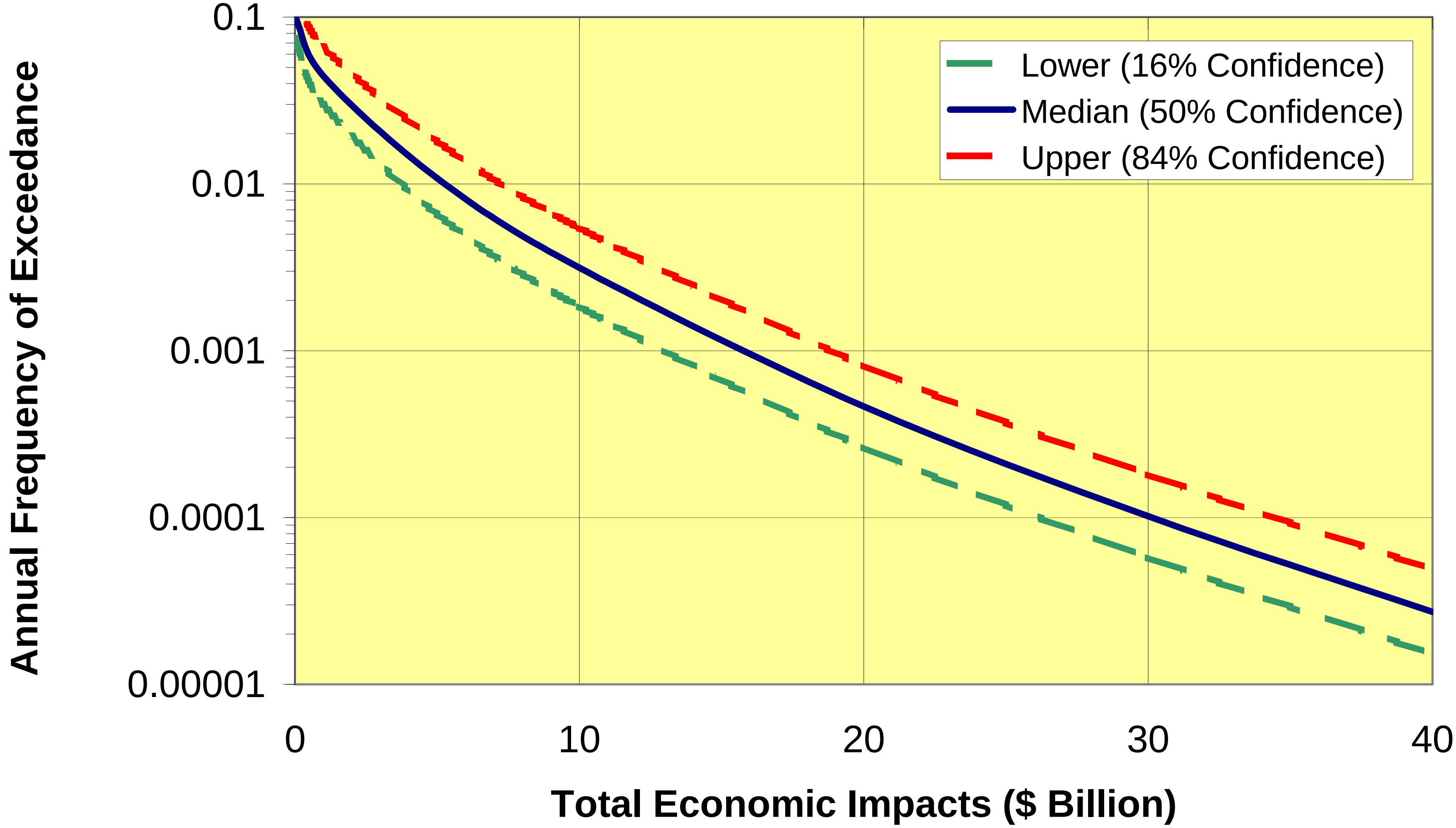



**Figure 13-19b Annual Frequency of Exceeding Total Economic Impacts Due to Seismic Events**

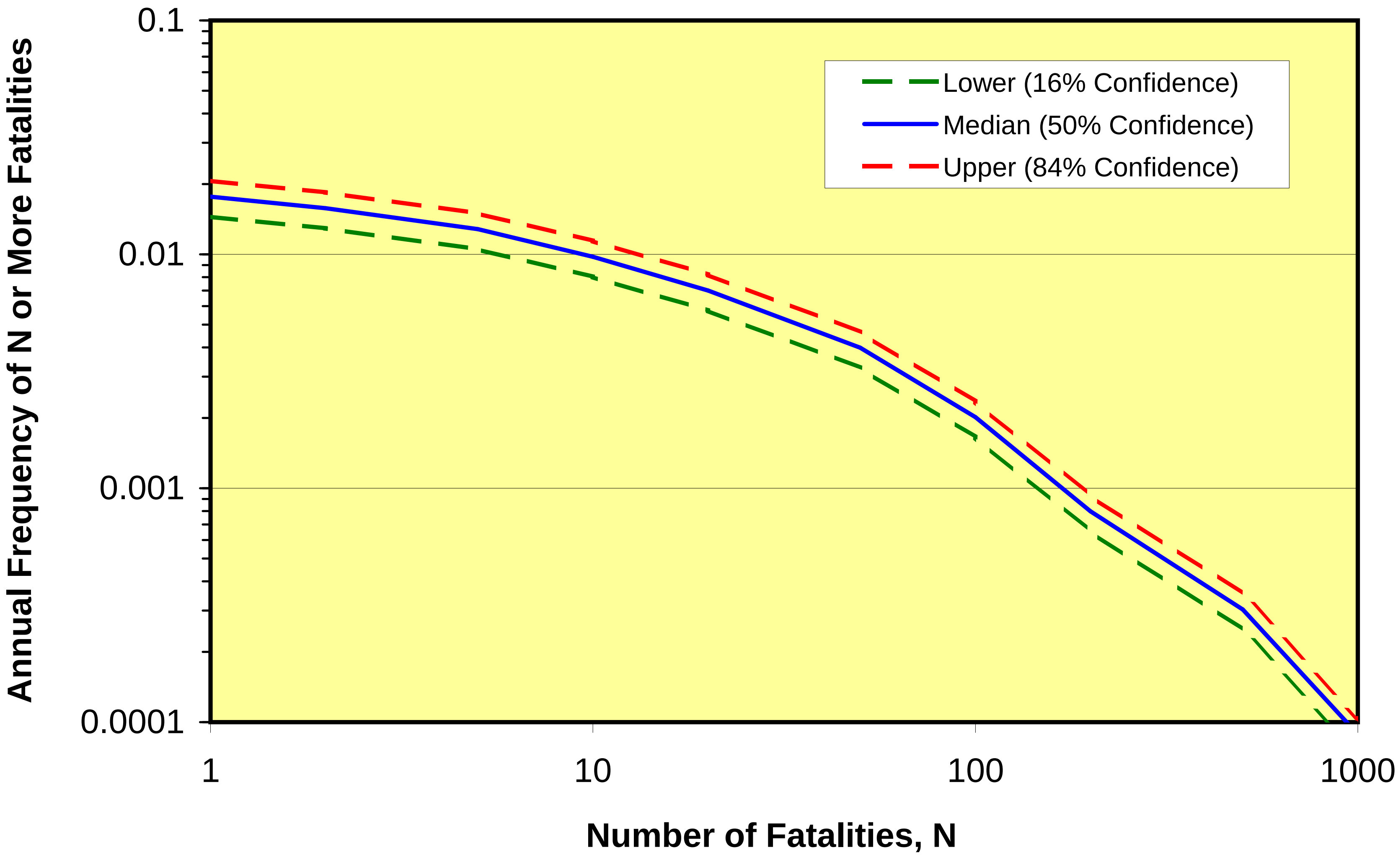



**Figure 13-20 Expected Life Loss due to Earthqakes**

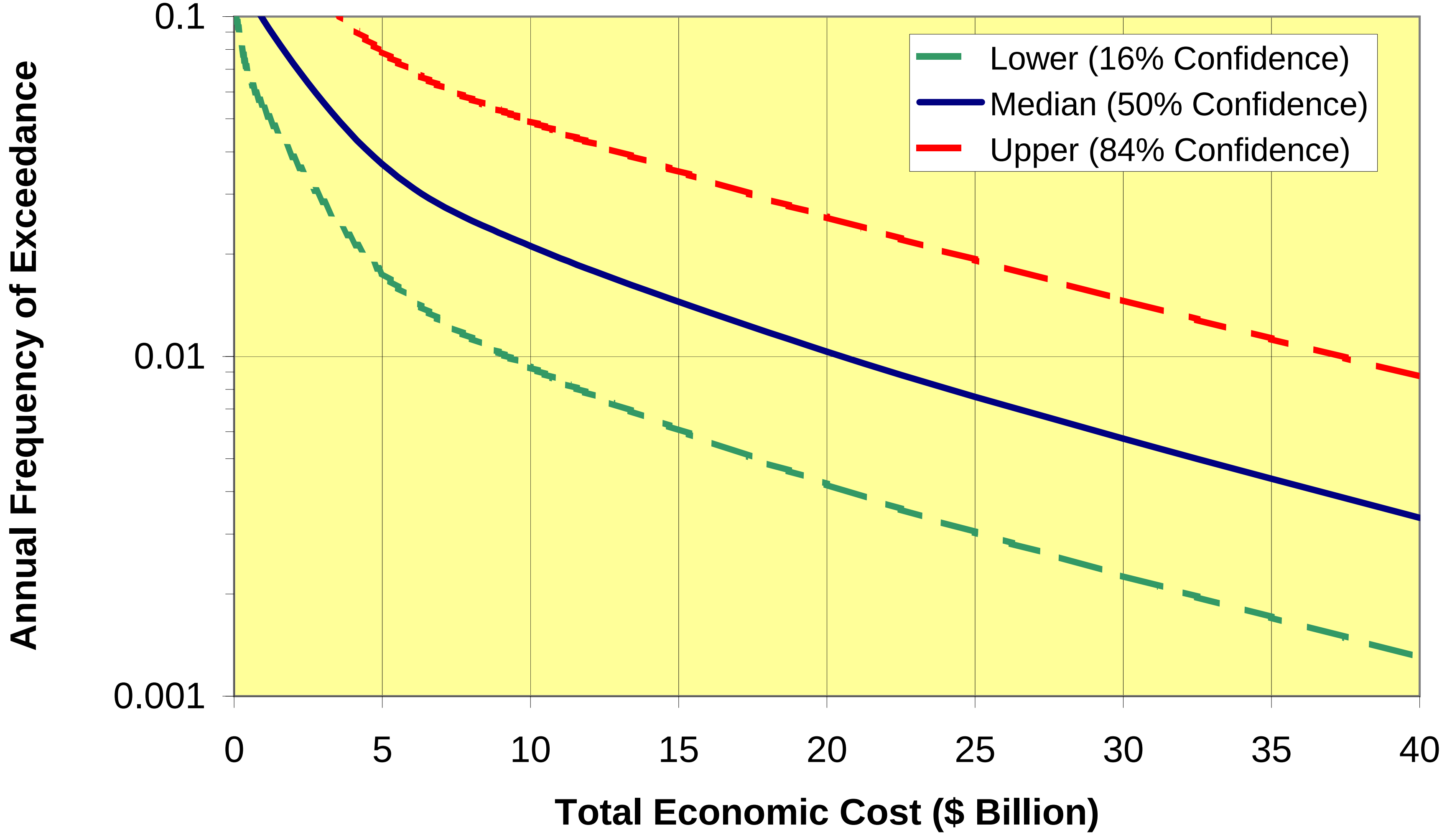



**Figure 13-21a Annual Frequency of Exceeding Total Economic Cost due to Hydrological (Flood) Events**

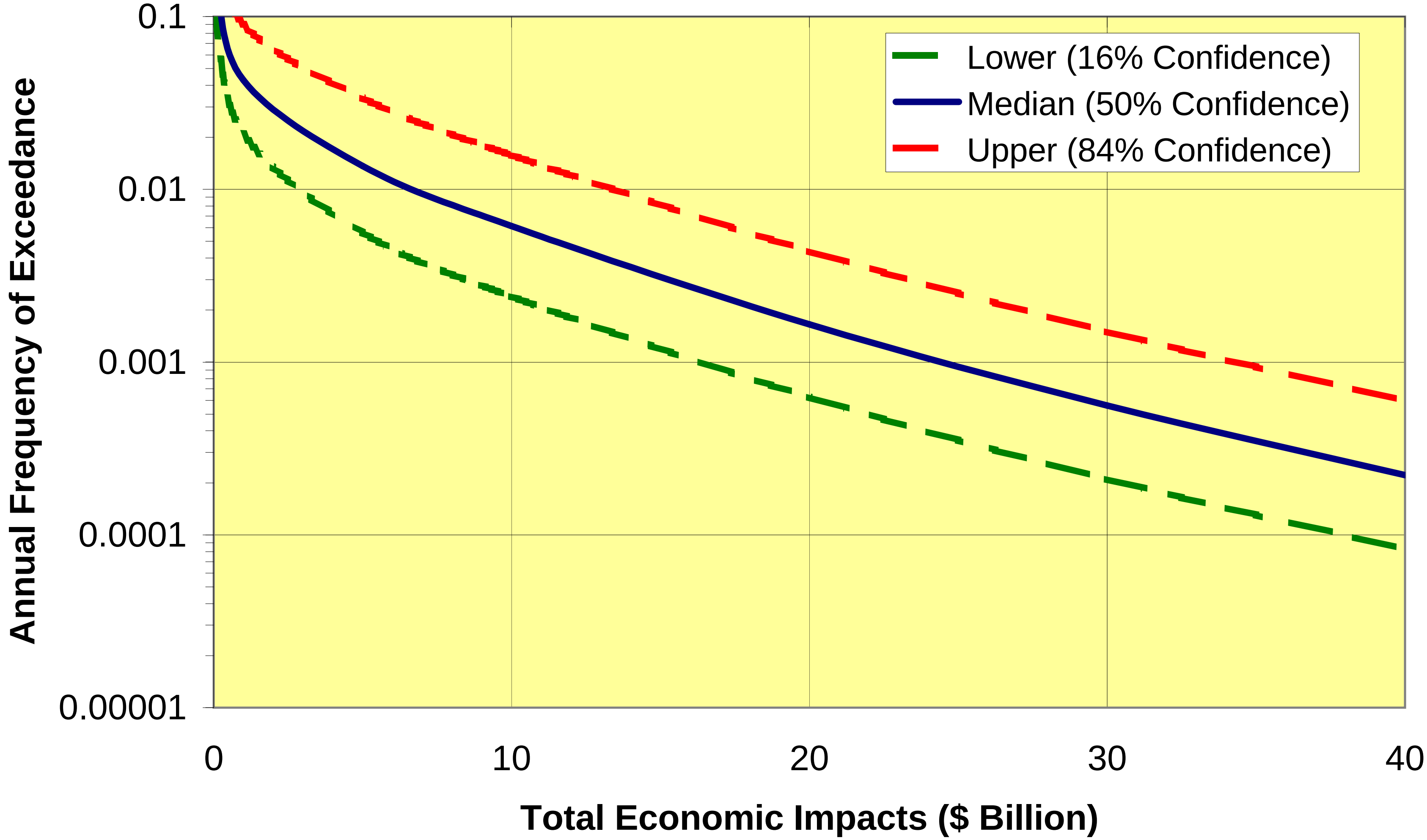



**Figure 13-21b Annual Frequency of Exceeding Total Economic Impacts due to Hydrological (Flood) Events**

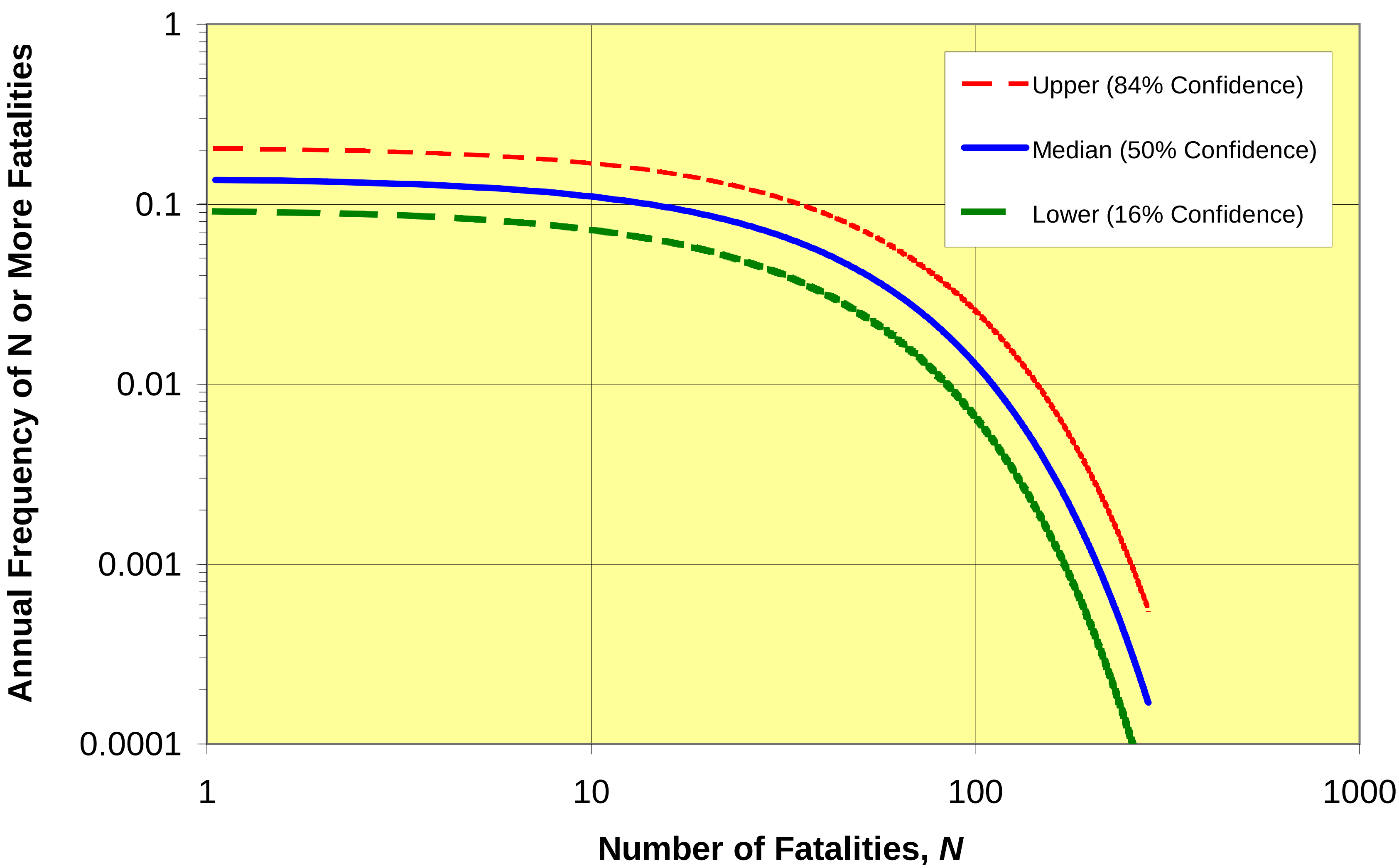



**Figure 13-22 Expected Life Loss due to Hydrological (Flood) Events**